ORTHOPEDIC APPLIANCES

Second Edition

ORTHOPEDIC APPLIANCES

The Principles and Practice of Brace Construction

By

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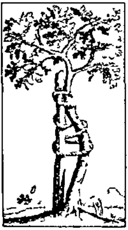

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To

Betty Jane Henry

and

Robert Lee Henry

For their tireless efforts, energy, and foresight in organizing The National Hemophilia Foundation and, more recently, Hemophilia Research, Inc., for study and experimentation in the treatment of hemophilia patients. These two pioneers have been responsible for the growing interest in brace constructions designed expressly for hemophiliacs so that many victims of this still incurable disease no longer must live as hopeless cripples. Instead, they have undergone rehabilitation that is almost beyond belief. Throughout the world, hemophiliacs and their families owe Robert Lee and Betty Jane Henry everlasting gratitude.

FOREWORD

In the quarter century since publication of the first edition of *Orthopedic Appliances, the need for a new edition to encourage bracemakers and* orthopedic surgeons to explore the full potential of orthopedic treatment along modern scientific lines has become increasingly apparent. The large accumulation of requests for information in the field made it additionally *urgent that a second edition of this volume be offered at this time.*

As the first edition, published in 1938 by the Oxford University Press, was quickly absorbed by the market and publication rights reverted to the author in the intervening years, I decided to renew a recent association with the American publisher, Charles C Thomas, who published my previous book, *Hemophilic Arthropathies,* in 1958. As I anticipated, the collaboration was, once again, a pleasure and a privilege.

This project would not have been possible without the support of Hemophilia Research, Inc., which administered the generous grant made by Miss Florence L. Schepp, providing the necessary funds for the preparation of the manuscript and illustrations, and for publishing this edition. It is difficult to express my gratitude for this assistance.

My sincere thanks are due to Mr. Alfons R. Glaubitz, C.O.P., Chief, Orthotic Prosthetic Facility, State Hospital for Crippled Children, Elizabethtown, Pennsylvania, a scientifically minded bracemaker who contributed his vast knowledge of brace constructions and brace shop procedures to this as well as to the previous edition.

Mr. Paul Schumacher, C.O., manager of the original Lenox Hill Brace Department and now in charge of the hemophilia workshop at Lenox Hill Hospital, deserves special recognition for his role in the development of individualized hemophilia Hessing braces with their spring joints and *locking devices.*

In editing the manuscript for publication, Mrs. Carol S. Diamond has presented the text and illustrations in such a way as to provide readable yet comprehensive accounts of the uses of the many orthopedic appliances described in these pages and the techniques for their construction. My thanks are due for her skill in this undertaking.

I am also indebted to The Bergman Associates for the uniform excellence of the new illustrations in this edition which, in every instance, heighten the clarity of the presentation.

Finally, I should like to acknowledge the courtesy of various authors, editors, and publishers who allowed me to reproduce thirty nine illustrations in the first edition of *Orthopedic Appliances.* A number of these appear again in this second edition.

Henry H. Jordan, M.D.

INTRODUCTION

The offspring of general surgery and the ancient craft of bracemaking, orthopedic surgery has become a well defined and universally recognized specialty It shares with other specialties of medicine many diagnostic methods and therapeutic resources Since the era of asepsis and antisepsis and following the introduction of anesthesia, the orthopedic surgeon has been interested chiefly in the surgical approach

Strangely enough, bracemaking, the oldest branch of orthopedics and the only area in which it remains entirely independent of the other specialized fields of medicine, has been largely neglected by the orthopedic surgeon Instead of exploring the therapeutic possibilities of orthopedic appliances along modern scientific lines, the orthopedic surgeon has largely delegated responsibility for design and construction of appliances to the bracemaker Although the original prescription is usually made by the orthopedic surgeon, there is little or no cooperation between surgeon and bracemaker in the actual manufacture and fitting of the appliance Yet it is this very cooperation, based on training and experience on both sides, that I shall emphasize throughout these pages as basic to superior bracemaking and successful treatment with orthopedic appliances

Because this cooperation between the orthopedic surgeon and his bracemaker has been too often lacking in the past, the field of bracemaking has become, on the whole, increasingly sterile, forfeiting the significant place it deserves in the armamentarium of orthopedic surgery As I believe this trend should be reversed, a second edition of *Orthopedic Appliances* is offered here in the hope that both orthopedic surgeon and bracemaker will find in it material that will provide answers to some of the many problems of bracemaking, and stimulate them to the broader use of orthopedic appliances designed along modern scientific lines As the introduction to our first edition, published in 1939, stated

> The purpose of this book is to quicken the interest of both orthopedic surgeon and bracemaker in the problems of construction and building of orthopedic appliances on modern scientific lines, and to give the bracemaker a better understanding of the requirements of modern orthopedics as far as the appliances are concerned, and the orthopedist a better understanding of the facilities and the limitations of bracemaking and of the influence which he can exert on the production of better braces This book aims at giving a cross section of modern bracemaking as a foundation on which the orthopedic surgeon and the bracemaker should develop new ideas

This edition will differ from the original, not only in its selection of old and new appliances of choice, but also in reducing to a minimum all discussions of medical indications These will be included only insofar as they are necessary to explain the purpose of any appliance illustrated within these pages

During the more than twenty years since *Orthopedic Appliances* was first published, the *Orthopedic Appliances Atlas** has appeared in the United States and E J Nangle's *Instruments and Apparatus in Orthopedic Surgery*† was printed in Great Britain Both works contain a generous sampling of illustrations from my original volume Soon after World War II, and continuing to date, there has been an ever-increasing number of requests for copies or reprints of *Orthopedic Appliances*, evidencing the persistent interest of hundreds of bracemakers throughout the United States and of many of the large group of men who have made orthopedic surgery their specialty As the first edition was absorbed by the market soon after publication, this second edition is now available to meet the demand in the field

The principles of scientific bracemaking have not changed In addition, most of the brace constructions illustrated in the first edition have stood the test of time Where, however, scientific progress in materials and manufacturing processes has made them obsolete, they have been dropped from the present edition

There have been many changes, of course, in the general field of orthopedics They concern, largely, the new identity of the orthopedic patient

Many diseases and their sequelae calling for orthopedic appliances which were discussed in the first edition, have disappeared or are only rarely seen Here, I would mention congenital syphilis syphilis of the central nervous system (tabes dorsalis), rickets, with its once large crop of bowlegs, knockknees, and scoliosis tuberculosis of bone and joints with the gibbus of the dorsal spine, and even paralytic deformities from poliomyelitis, as few new cases will require bracing with the dramatic conquest of this disease Congenital deformities seem to be increasingly rare, where present, they have become more amenable to definitive surgery The incidence of hip dysplasia has decreased, and the fully developed talipes equinovarus occurs less frequently, to be succeeded, apparently, by the lesser problems of metatarsus varus and pes adductus anterior

Many conditions, of course, continue with the same incidence Others have gained in importance from the viewpoint of bracemaking In the past quarter of a century, man's longevity has increased beyond expectations Not only will many of us reach our eighties and nineties, we shall also remain much younger in the process This means that man continues with

*Vol I The American Academy of Orthopedic Surgeons Inc, Ann Arbor Michigan J W Edwards 1952

†Oxford Blackwell Scientific Publications, 1951

activities which expose him, in his later years, to trauma of all kinds, particularly to fractures In the constantly increasing group of the aged, there are many more cases of bone pathology, such as osteoporosis and Paget's disease More cases of cancer are detected and kept alive for longer periods, thereby allowing time for the development of bone metastases The risk or the fact of pathological fractures of the extremities calls for prevention or treatment with orthopedic appliances With improved medical care, more patients return to active living after a cerebral vascular accident with a residual spastic pes equinus requiring bracing Rheumatoid arthritis and degenerative joint diseases (malum coxae senilis) may benefit from or rely upon orthopedic appliances with or without previous attempts at rehabilitation by surgery

Another group which had not appeared on the scene when our first edition was published has come into the spotlight of modern bracemaking Small as it is numerically, the very life of these patients depends to such an extent on the status of bracemaking throughout the country that publication of this second edition became imperative I am speaking here of hemophilia with its crippling arthropathies and myopathies, until fairly recently regarded as a hopeless disease With the gradual realization that progress in hematology could preserve the life of the hemophiliac, there came the knowledge that specific orthopedic treatment was essential to repair the tremendous damage caused by hemorrhages into bones and joints

As open surgery and the customary methods of correction of deformities could not be employed because of the risk in hemophilia, it was natural to turn to a modality of treatment used successfully in the past in non surgical correction of contractures and deformities caused by infantile paralysis Personal experience with the sound principle of subliminal forces introduced by F Mommsen in 1922 in a paper entitled 'Die Dauerwirkung kleiner Krafte bei der Kontrakturbehandlung (Quengelmethode) * ("Continuous Action of Small Forces in the Treatment of Contractures") suggested its adaptation to the special requirements of hemophiliacs

We began treatment of our first hemophilia patient in 1946 with correction of a long standing flexion deformity of the knee joint from hemophilic arthropathy Since then, our work, sponsored in large part by The National Hemophilia Foundation, has led to the development of atraumatic plaster of Paris techniques and the construction of individualized orthopedic appliances that have resulted in the rehabilitation of hemophilia patients to a degree that is almost beyond belief The very specific requirements of the hemophilia victim and the unusual precautions that must surround the bracing of this particular patient have led to modifications of standard orthopedic appliances which, for the sake of simplicity, we call Hemophilia braces It is partly because of these specially developed appliances that the Hemophilia Service at Lenox Hill Hospital in New York City has be-

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come a treatment center that has given hope to hundreds of hemophilia sufferers throughout the United States

For the sake of economy as well as for the obvious reason of convenience to the patient, treatment of the hemophiliac must certainly be established on a local basis It has been unfortunate that all of our attempts in the past fifteen years to decentralize such treatment by organization of local chapters of The National Hemophilia Foundation throughout the country have suffered from the fact that brace shops equipped to provide orthopedic treatment for the hemophiliac are almost non existent at the local level It is, therefore, a primary purpose of this text to provide the requisite information on construction of individualized Hemophilia braces in order to encourage bracemakers outside of New York City to develop this skill and provide the hemophilia patients with proper appliances for treatment and rehabilitation

Despite the decline in certain diseases and deformities requiring orthopedic appliances, the demand for superior bracing by scientifically correct orthopedic appliances remains a challenge to orthopedic surgeon and bracemaker alike The number of patients requiring their help is certainly great enough to justify continued teaching in the field and exploration of new methods and devices for easing the existence of that segment of the population that is either temporarily or permanently crippled

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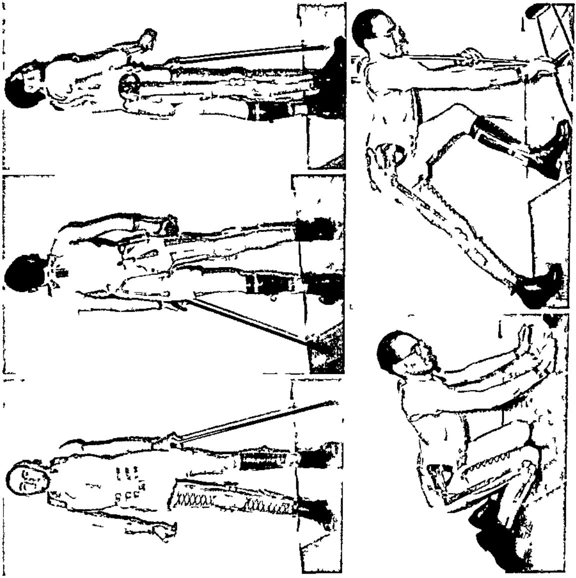
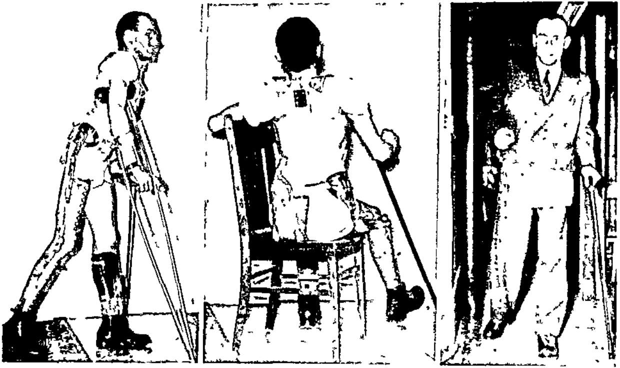
ORTHOPEDIC APPLIANCES





Frontispiece With the correct orthopedic appliances, an otherwise completely helpless young man suffering from progressive muscular dystrophy is able to lead an almost normal life Braces manufactured by Mr Albert Ilien and Mr. Gustave Maxe (Lenox Hill Orthopedic Co), 1950

Chapter 1

PLASTER OF PARIS TECHNIQUE

Plaster of Paris is used more frequently than any other material in orthopedic surgery and in the treatment of fractures. It might therefore be assumed that its technique has become so routine to surgeons, particularly those in orthopedics, as to render this chapter superfluous. There are, however, many ways of applying a plaster of Paris cast and making a plaster of Paris mold, and these variations in technique by no means guarantee the high degree of satisfaction that can result from skillful use of this rewarding material. Uniform success with plaster of Paris is a matter of personal experience based upon extensive practice. I often recall Hans von Baeyer's caveat: "Don't think that you know anything about the application of plaster of Paris until you have, with your own hands, made at least two or three thousand plaster casts for foot plates."

Since our text is not concerned with the general use of plaster of Paris in the treatment of fractures or as a means of fixation in orthopedic surgery, this chapter will be restricted to the role of plaster of Paris in bracemaking. The subject may accordingly be divided into two categories representing its major functions.

The first has to do with plaster of Paris as a substantial part of an orthopedic appliance for time-limited use. Here, for example, we would include a plaster of Paris bed for tuberculosis of the spine, a plaster of Paris jacket for lower back pain or sacroiliac disease, corrective and protective night splints for the wrist or the lower leg and foot, appliances for reduced congenital dislocation of the hip, and splints or shells for post-operative use in plastic surgery which demands close cooperation between orthopedic surgeon and plastic surgeon in the preparation of such appliances prior to surgery.

The second category refers to plaster of Paris for negative molds and positive models for orthopedic appliances.

Plaster of Paris is a white powder made from the mineral gypsum which is dehydrated calcium sulfate, possessing the chemical formula $CaSO_4 \cdot 2H_2O$. While ancient history reveals the importance of gypsum in the various fields of art, we find the Egyptians, under the Pharaohs, using it for fracture casts as early as 1200 B.C. We next hear of the Arabs recommending it for this purpose in 1796, and by 1800 medical records indicate that, in Germany, plaster casts were being made with gypsum. In Holland, half a century later, Mathysen was using this material for plaster of Paris bandages.

The gypsum is crushed, pulverized, and subjected to a heat of approximately 250°F in order to drive off the water of crystallization (about 21 per cent). Mixed with water, the powder undergoes a process of recrystallization called "setting." The two reactions may be expressed in a single chemical equation:

$$\underset{\text{Gypsum}}{2(CaSO_4 \cdot 2H_2O)} \rightleftharpoons \underset{\text{Plaster of Paris}}{(CaSO_4)_2 \cdot H_2O} + \underset{\text{Water driven off}}{3H_2O}$$

Plaster of Paris of good quality is somewhat insensitive to humidity and under proper conditions may be kept indefinitely. The poorer quality, however, is very sensitive to humidity and under improper conditions will recrystallize, producing lumps of crystal which

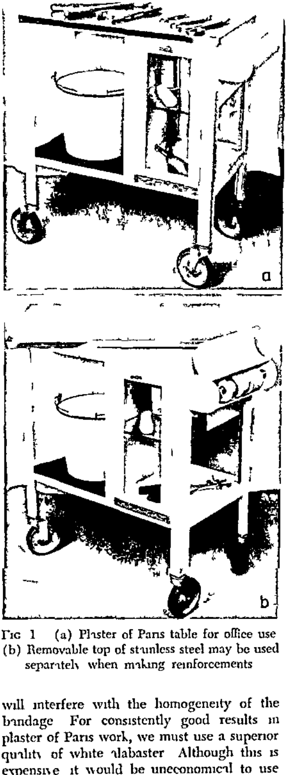


FIG 1 (a) Plaster of Paris table for office use (b) Removable top of stainless steel may be used separately when making reinforcements

will interfere with the homogeneity of the bandage For consistently good results in plaster of Paris work, we must use a superior quality of white alabaster Although this is expensive it would be uneconomical to use an inferior grade, as failure to obtain a perfect mold will lead to difficulties in brace construction and fitting which in the long run are much more costly than the initial outlay for high grade plaster Good quality orthopedic plaster must be at least 99 per cent pure gypsum pure white in color and very finely ground so that it has a floury feel when rubbed between the fingers The presence of grit suggests inadequate milling or gypsum crystals It must also have a uniform setting time The trade supplies plaster of Paris bandages labelled "extra fast fast and "slow" with setting time indicated on the wrapper Depending on the type of plaster initial setting is completed within two to twenty minutes

Proper storage of plaster of Paris is of great importance The supply must be stored in air tight wrappings in a dry place outside the plaster room if possible Only the quantity of plaster of Paris bandages necessary for immediate use should be kept in the plaster room Otherwise humidity and heat or splashes of water from the plaster of Paris procedure may affect unused plaster Opinions differ widely as to the best type of plaster of Paris bandage I favor one containing an abundance of plaster of Paris powder of superior quality spread on a cheap kind of gauze loosely woven to insure a sufficient amount of plaster within the gauze and easy penetration of the whole bandage by the water I discourage the use of bandages made of crinoline as these contain starch glue or similar chemicals which have an undesirable influence on the handling of plaster of Paris bandages and which slow down the processes of setting and drying Bandages must not be too tight or too loose they must be uniformly rolled and penetrated with plaster

The work in the plaster room will be greatly facilitated if bandages are standardized as to length width and weight This will enable the orthopedic surgeon to determine in advance how many bandages he will need for a certain type of cast or mold thereby increasing the speed of the work and insuring a certain degree of uniformity Many orthopedic

surgeons prefer using one size, such as a 5-inch bandage for all work On a large service, it may be necessary to have an ample supply of 5 and 6 inch bandages and a few 2-inch and 10 inch bandages ready In any case, standardization of plaster room procedure is essential

While plaster of Paris bandages form the main supply of the plaster room, the following materials will also be frequently used loose plaster of Paris that is stored in air-tight containers and used for finishing appliances such as jackets and night splints, large plaster of Paris beds and shells, and occasionally for the immediate casting of a mold in a case of special interest to the orthopedic surgeon, large sheets of gauze, white piano-maker felt, burlap, foam rubber, basswood and metal splints, gauze bandages, paper bandages, flannel bandages, and, last but not least, stockinette in various widths The Stryker electric cast cutter is excellent for cutting plaster of Paris negatives or molds If this is not available, a Gigli saw will be helpful For some appliances, various types of hinges and other hardware may be necessary, but these should be prepared for the individual case and need not be kept in stock

A number of tools or instruments will be needed to trim and cut the plaster and to remove a cast The widely used Stille plaster cutter in its various modifications, duck bill, plaster spreader, bandage scissors of various sizes, knives, and a sharpener are usually found in every plaster room A few words may be said about certain tools, however, which are of special value in making good plaster molds

1 A knife with a strong, thin blade (as used by leather workers), with a rather thick handle designed to contain the major part of the blade and permit it to be pulled out to any desired length This type of knife is easy to sharpen with a few strokes on the oil stone It gives a straight, clean cut and facilitates the cutting of a plaster mold by small movements in a direction vertical to the cut, thereby wedging the cut edges and allowing

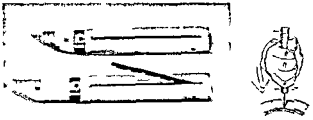


FIG 2 Plaster of Paris knife Insert shows correct handling of knife in cutting a cast

easy penetration into the deeper layers without risking too deep a cut

2 The oscillating Stryker electric cast cutter that permits a cast to be cut into any desired pattern so that the component sections may be lifted off the patient without wrenching, levering or in any way changing the posi-

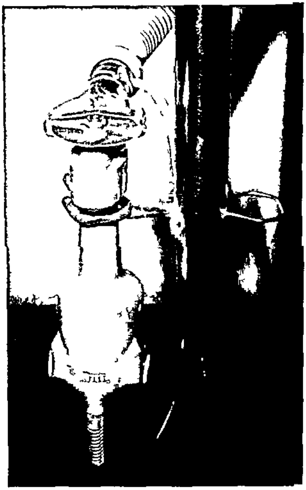


FIG 3 Stryker electric cast cutter with vacuum attachment

tion of the part of the patient under treatment

Where the Stryker electric cast cutter is not available, the Gigli saw may be used although this instrument does not insure the same atraumatic handling of the patient Before application of the cast the saw is placed on a strip of thin felt and held in position by a few turns of crepe paper or gauze bandage When the cast is completely set handles are attached to the protruding ends of the saw and the cast is actually sawed apart

Finally, it must be mentioned that rubber gloves should be worn for all plaster work, not simply to protect the surgeon s hands but chiefly to insure greater smoothness of the cast It is much easier to rinse plaster of Paris crystals and lumps from rubber gloves than from the skin

The following general principles apply to both plaster of Paris appliances and molds In order to guarantee rapid and smooth work sufficient assistance is necessary The amount of help required will vary according to the type of work When preparing a cast for a pair of foot plates the orthopedic surgeon may work with one other person preferably a plaster room nurse When making a mold for a spinal brace to fit a paralytic scoliosis in a patient with paralyzed legs it is essential to have three or even four well trained assistants or nurses The surgeon and his assistant must know in advance all the details of the procedure to be followed to insure the nec-

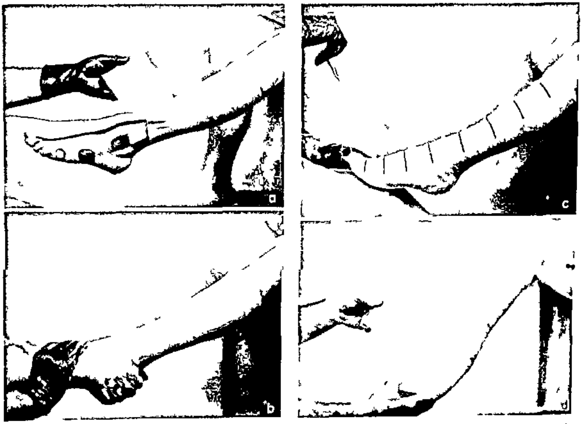


FIG 4 (a) Bony prominences are landmarked The Gigli saw is placed on a strip of felt and held by a crepe paper bandage (b) The foot is held in the desired position until the cast is completely set (c) The cast is marked the Gigli saw cuts the cast in a straight line (d) Using a gauze bandage, the mold is carefully closed

essary speed The technique should be standardized as mentioned above to determine the number and size of plaster of Paris bandages required

The work will depend to a large extent on the proper condition of the bandage when handed to the surgeon This important point is frequently underestimated The quality of the cast is impaired if the plaster is not homogeneous it can be homogeneous only if each bandage contains equal quantities of plaster of Paris and of water (of the same temperature) and is used at the same stage of setting

The setting time is also influenced by the temperature of the water with cold water used for slow and warm water for fast setting I prefer water of 103°F temperature A bucket of the size described can hold sufficient water for soaking approximately six 5 or 6 inch bandages As a rule two buckets should be used at the same time for soaking with a third bucket available for expressing superfluous water from the soaked bandages We use a stand that rolls easily on casters and contains two buckets placed at the height of an ordinary table and a third bucket that stands between the other two at a slightly

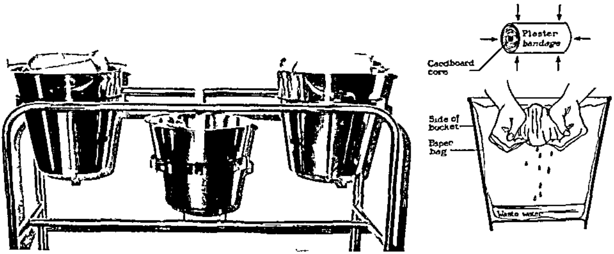


Fig 5 (Left) Movable stand with three buckets (Right) Correct handling of plaster of Paris bandages small arrows indicate the direction of the pressure when water is expressed

In our procedure water for the bandages is contained in large buckets holding approximately 8000 cc A paper bag (garbage can liner) is placed inside the bucket to catch any loose plaster that would otherwise clot or cake at the bottom of the pail and obstruct the pipes if the sink was not fitted with a special device for draining plaster A deep bucket is necessary as the time needed for penetration of the bandage by the water depends upon the pressure of the water If the cast is applied by a well trained team of workers fast setting plaster may be used to advantage

lower level for expressing the water The plaster room nurse is instructed to change the water in each bucket after six bandages have been soaked

The orthopedic surgeon must decide when the first bandage should be immersed After that the nurse proceeds to replace every bandage taken from a bucket with a new one until the previously determined number of bandages has been used or the surgeon gives other directions In the soaking process the bandage is placed in the bucket on one end and dropped into the water where it slowly

sinks to the bottom It must not be touched or kept in the hand until it is completely soaked and ready to be removed from the water This will be the case when air bubbles cease to rise When the bandage is to be removed from the water, both hands are introduced into the pail with the finger tips touching each other and the bandage is lifted out of the water without pressure It is then held into the empty waste water bucket and the water is expressed by pressing both halves of the bandage between the four extended fingers and the thenar and, finally, by pressing both hands against each other in the longitudinal axis of the bandage Exactly how much water should be expressed is a matter of experience and varies from case to case I dislike any other method of expressing the water from the bandage, especially twisting and pulling manipulations, as these interfere with the smooth rapid unrolling of the bandage and with its homogeneity After expressing a sufficient quantity of water, the bandage is ready for immediate use and is handed to the surgeon with an inch or two of the end rolled off so that no time is lost searching for its beginning

When applying the cast, one must make sure that the plaster of Paris bandage is rolled on smoothly, rapidly, and continuously, without any pulling motion as this would cause undue constriction and disturb the homogeneity of the cast If high grade plaster of Paris is used under the proper conditions discussed above, it will not be necessary to continually rub in plaster while unrolling the bandage A large quantity of plaster of a cream like consistency will be available and a few strokes with the flat hand will suffice after several turns of the bandage have been applied, to produce a smooth plaster The surgeon must apply the bandages according to a definite plan or system, avoiding weak spots in certain types of casts, and preparing in advance for efficient removal of the cast

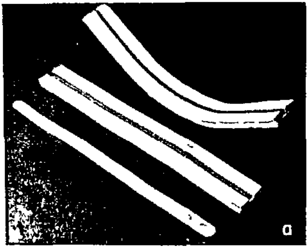
These general principles for plaster of Paris technique apply whenever the material is used The technique varies according to whether one makes plaster of Paris appliances for time-limited use or plaster of Paris molds As I regard the use of plaster of Paris as such an important factor in brace construction, I prefer to focus in this chapter on the basic features of plaster of Paris which, in my experience, deserve to be discussed in detail rather than scatter references to them throughout the text We can accomplish this with a few practical examples

THE MODEL FOR FOOT BRACES AND FOOT PLATES

The model for foot braces and foot plates deserves special discussion The most frequently used model in the manufacture of orthopedic appliances, it is one in which most mistakes are made These, with rare exceptions, lead to complete failure of the foot plate and are partly responsible for the bad reputation of such appliances made to plaster casts The indications and prerequisites for the various types of foot plates and especially the two major groups we recommend will be discussed later in a special chapter on foot braces At this moment, we are concerned only with the procedure of taking an impression and making a model for a foot brace Regardless of which type of brace is used, the plaster of Paris model will be the same

Position of the Patient

The patient sits on a table with the legs hanging down The muscles should be completely relaxed in order to enable the surgeon to mold the foot into the correct position We must stress the point that our goal is a positive model of the foot in its correct position for weight bearing standing and walking and that we have to avoid an impression which represents the deformity of the foot rather than the correction This cannot be achieved by the old method of placing the patient s foot in a basin of plaster of Paris cream The method described by Royal Whitman for making a mold of the patient s foot for his type of foot brace is a suitable proce



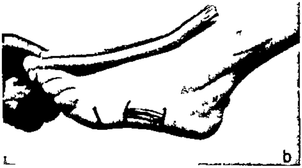


FIG 6 (a) Splint for cutting a plaster of Paris cast of the foot. (b) The foot is landmarked for a celluloid or fiberglass foot plate. The cutting splint is in place. (c) One 5 or 6 inch plaster of Paris bandage is applied beginning at the ankle.

(d) A board is pressed against the sole of the foot in order to obtain an impression of the details. (e) The foot is held in corrected position, heel in supination, forefoot in pronation. (f) The sole is carefully molded for support of the os calcis and the metatarsal arch. (g) The cast is cut in a straight line on the cutting splint. (h) The mold is ready for casting.

dure which we have used in many cases Our experience, however, based upon at least 25,000 pairs of foot plates, confirms the technique described below as the best and simplest method of obtaining a perfect model of the corrected foot for any type of foot brace we wish to use As a rule, plaster casts have to be made of both feet To simplify the description, however we shall discuss the procedure for one foot only For the less experienced, it is advisable to make the cast for one foot at a time, while an expert will be able to make the negative molds of both feet simultaneously without neglecting important details of each foot

Preparation of the Foot

Certain landmarks have to be outlined on the foot with an indelible pencil which will transfer the marks to the negative and from there to the positive model of the foot We moisten the skin and outline the landmarks On the medial aspect or tibial border of the foot, we mark the first metatarsophalangeal joint, and the position of the scaphoid, especially if this is prominent, on the lateral aspect or fibular border of the foot, the fifth metatarsophalangeal joint and the more or less prominent tuberosity of the fifth metatarsal bone, on the sole of the foot, the head of the first metatarsal and, in case of metatarsalgia, the plantar prominent heads of the second third and fourth metatarsal bones In addition, we mark points to be relieved from pressure, such as plantar warts, painful callosities, and the projection of a spur of the os calcis or a painful bursa at this site

To cut the cast, we use a special splint on the dorsum of the foot This is made in various lengths for adults and children It consists of a heavy strip of leather about an inch wide on which a thin flexible strip of metal, usually zinc, is held in place by two lateral longitudinal strips of leather sewn to the basic leather strip This appliance may be used over and over again It is flexible, may be washed with soap and water, and provides for fast, straight cutting without risk of injury to the skin The bulk of this appliance does not interfere with the exactness of the model as we are not interested, for this particular purpose, in the dorsum of the foot

Application of Plaster

When the landmarks are outlined, a 5 inch plaster of Paris bandage is immersed and soaked and the excess water is carefully expressed The bandage is then applied to the foot beginning at the ankle joint and running down to the toes To avoid constriction, it is applied rather loosely while, at the same time, plaster is massaged into the sole of the foot Special care must be taken to have a sufficient amount of plaster under the heel, frequently the weak point in this type of cast If the foot is small, we have sufficient bandage to enclose the toes This facilitates casting the mold but it is not essential It is more important to get a correct and strong impression of those parts of the foot which will eventually be covered by the brace As soon as the plaster of Paris bandage is applied to the foot and the homogeneity of the cast insured by rubbing the plaster and distributing it well over the entire surface, the sole of the patient s foot is placed against a wooden board which is slightly larger than the sole The only purpose of this procedure is to guarantee a good impression of the entire surface of the sole and not to take an impression under weight bearing While the plaster is setting rapidly, the foot is held in the desired position

While this position depends upon the type of deformity and the correction to be supplied by the foot brace, some general remarks may be indicated Most significant for the cast as well as for the purpose of treatment is the heel and its relation to the lower leg and the ankle joint We therefore have to mold our plaster carefully to the heel In correcting pes planus or pes valgus, for example, it is very important to support the distal parts of the os calcis and here the cast will need careful modeling by pressure with the operator's thumb Moreover, it is important to keep in mind the type of shoe and par-

ticularly the height of the heel to be worn by the patient. While preparing the cast the foot has to be placed in the correct degree of equinus corresponding to the height of the heel. If this is neglected, the foot brace will need additional correction at the time of fitting in order to settle in the shoe. Such a change in a finished foot plate may ruin the entire appliance.

Next, we have to consider the position of the metatarsal region of the foot and the toes. It is essential that the head of the first metatarsal bone, the chief weight bearing point of the anterior foot, is in sufficient plantar flexion, in other words, the metatarsal region must be held in pronation and not, as is frequently seen, in supination. In some cases we have to model out a special metatarsal support at the right place, but more important than this metatarsal support is the compression of a pes transverso planus in the transverse direction at the metatarsal region. There are indeed so many factors which have to be considered in the short time necessary for the plaster to set that this procedure is difficult to describe in detail. As we have said before, it is a matter of experience, and sometimes even an expert will find himself obliged to discard a cast and make a new model because he has not been able to make the desired correction at the first attempt.

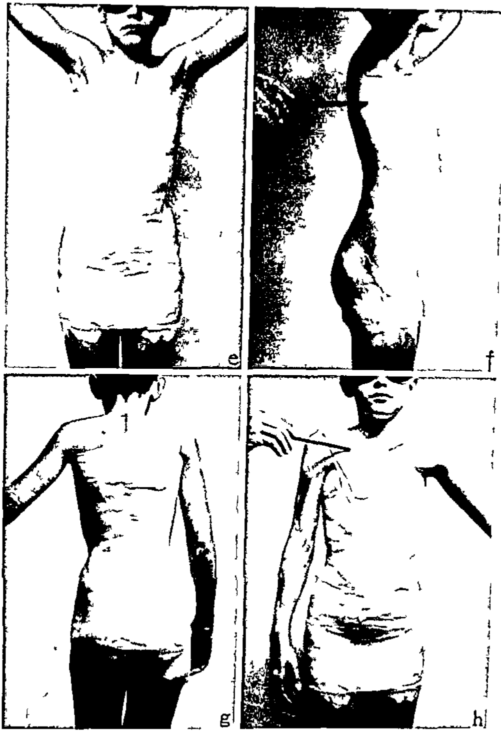
As soon as the plaster of Paris is set, which will take from three to five minutes, it is cut with a strong knife in the trough of our special splint. It is advisable not to cut the entire length of the cast but to leave a small bridge at the toes and then to remove the cast from the foot like a shoe. At this moment, it is important that the foot is completely relaxed and that the patient does not try to help the operator remove the cast. The cast is held together with a piece of gauze bandage or a rubber band and the patient's name, the date of fitting, the type of brace to be made, and any additional remarks for the man in the workshop are written on the cast.

The Positive Model

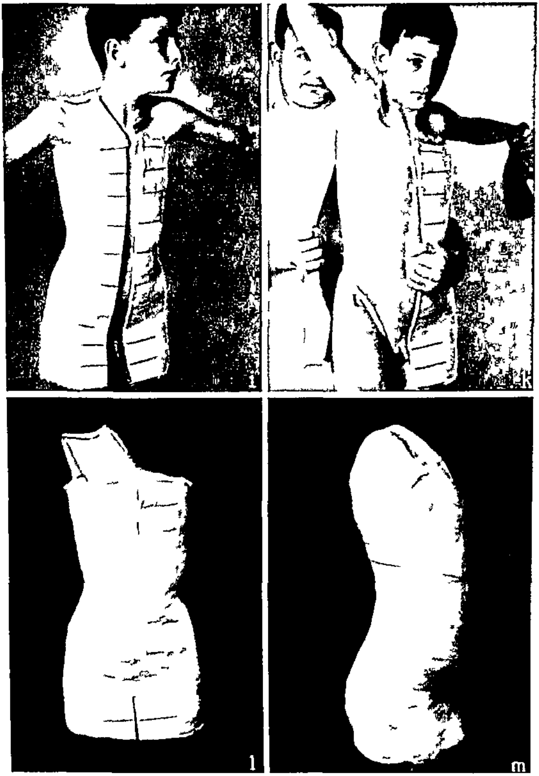
The small mold of a foot will be sufficiently dry for further processing in about one hour. Poorer quality plaster is frequently used for casting. Particularly for foot plates, however, we prefer the same quality of white alabaster as we use for our general plaster work. The negative may be prepared by rubbing in talcum powder, by rinsing the mold with soap and water, or by giving it a thin coat of oil although these procedures are unnecessary unless we desire to bring out special details in an unusual case. The negative is closed by wrapping it in paper or gauze bandages and placed on the table with the heel resting on a wooden block or bridge to stabilize the model in an inclined plane. A sufficient amount of cold, clean water to fill the negative (usually 600 cc for one adult foot) is poured into a basin and plaster of Paris powder is dropped into the water until some remains on the surface, which indicates that the solution is saturated. In this way, a homogeneous plaster of Paris cream will be obtained. This is now poured into the negative mold, very slowly and carefully, in order to give the air time to escape and to avoid air bubbles which would spoil the appearance of the positive model. If a good quality of plaster is used and the cream is of proper consistency, the positive model will harden within a few hours. As a rule, however, it is advisable to wait until the next day before proceeding with the model.

When the plaster of Paris in the mold is dry, the negative mold is cut along the line on the dorsum of the foot which has been used to remove the cast from the foot and an additional vertical cut is made on the posterior aspect of the heel. It is then easy to remove the negative envelope in one piece.

The positive model so obtained should require no further correction. It should represent the foot in the exact position of the desired correction. A faint trace of the landmarks will show on the model and will again be outlined with the indelible pencil before the model is handled.



and posterior to the major trochanter (e and f) The cast is continued to the axillae and carefully molded to the lateral wall of the thorax (g) The right shoulder is included (Actually the cast would also cover the left shoulder but this has been omitted in this and the following illustrations for the purpose of clarity) (h) The



infra and supraclavicular regions must be well molded (i) The cast has been marked and cut in the median line and over the right shoulder (k) The cast is removed the patient turns out of the cast (l) The model is closed by matching the marks at the cuts (m) The model is finished with two or three plaster of Paris bandages

tion of the plaster of Paris the pelvis should be horizontal When one leg is shorter than the other compensation must be accomplished as far as possible by placing wooden boards of required thickness under the shorter leg Atonic abdominal muscles or large amounts of abdominal fat may seriously interfere with a correct mold It is therefore advisable to support a weak abdomen by strapping or an elastic bandage before applying plaster of Paris

When the surgeon is convinced that the patient s position is correct he will outline certain landmarks for the model in indelible pencil On the lateral aspect of both thighs the level of the greater trochanter will be marked with a horizontal line in front the anterior superior spine will be indicated with a little square or circle about the size of a penny Both clavicles will be highlighted with a double horizontal line to show the proper site for the infraclavicular pad In the back other landmarks will include the posterior superior spines or the position of the sacroiliac joints the projection of the spinous processes at the site of a lesion the spinous process of the seventh cervical or the first dorsal vertebra and in cases of scoliosis the direction of the intended corrective forces as determined by x ray

If these landmarks are well outlined with indelible pencil they will appear on the negative as well as on the positive model with sufficient distinction even if a stockinette shirt is used to protect the patient s skin from the plaster The landmarks must however be marked on the skin rather than on the stockinette

If a stockinette shirt is to be used it is put on with holes for both arms and should reach from the neck to the distal third of the thighs

Von Baeyer* has introduced a very simple and ingenious device to make the pelvis self modeling and we have used his technique for many years A flannel bandage about 1 inch wide and 8 feet long is moistened and placed around the patient s waist running over the iliac crest anteriorly disappearing between the legs encircling both thighs and running forward in a horizontal line just below the trochanters The bandage is closed in front in the midline of the body with a safety pin or it is knotted and the ends are held by the assistant who is sitting in front of the patient This auxiliary strap if properly placed outlines the iliac crest and the trochanter of both sides exactly in the same way as the pelvic frame of the brace It assures the proper position of the plaster of Paris bandages without distorting the setting cast and without wasting time for additional molding

The patient is now ready for application of the cast The predetermined number of plaster of Paris bandages and splints made of 6 inch bandages are laid out to be handled by two nurses Both nurses prepare splint after splint at top speed for the cast while one assistant handles the bandages to be rolled over the splints Approximately twelve to twenty 6 inch bandages are required for the average adult Again the correct position of the patient is confirmed He may grip the two uprights of the frame with his hands and hold his arms abducted at a right angle in the shoulder joints keeping the elbows comfortably flexed One assistant sits on a low stool in front of the patient holding the ends of the self modeling pelvic strap He will be chiefly responsible for maintenance of the patient s position throughout the entire procedure and for stabilization of the pelvis during the pelvic part of the work A second assistant will act as partner to the surgeon in applying and molding the wet plaster to the body The splints start below the trochanter and gradually move upward until a cast of sufficient thickness is obtained from the trochanter level to the lumbar region that is three to five inches proximal to the iliac crest. When this level is reached a short intermission is necessary to allow for setting of the pelvic part of the cast As soon as the plaster begins to set the assistant sitting in front of the

*Hans Ritter von Baeyer late Professor of Orthopedic Surgery University of Heidelberg Germany

patient holding the pelvic strap and stabilizing the pelvis transfers his hands to the region of the trochanters and presses the cast carefully to the trochanters avoiding impressions of the finger tips A fairly deep depression must result just posterior and superior to the trochanters The second assistant or the surgeon standing behind the patient takes care of the exact modeling of the plaster of Paris to the iliac crest the anterior superior spine and the lumbosacral region It is necessary to obtain an exact impression of the posterior aspect of the lumbosacral region in addition to the well defined iliac crests which are determined by von Baeyer s pelvic strap A fast setting plaster of Paris is used with fairly warm water It will take only a few minutes for the pelvic part of the cast to be sufficiently hard to keep its form It is then time to resume application of plaster of Paris splints up to the axilla At this stage the amount of traction suspension may have to be controlled or increased

When the plaster has reached the level of the axilla we come to the shoulder region which is the most difficult part of the cast At this point we have to change the position of the patient s arms and secure a perfect impression of the clavicular portion of the thorax without losing the very important impression of the lateral wall of the thorax just below the axilla At the same time the patient will begin to suffer from traction suspension if this is used and there is frequently a considerable degree of nervous tension in the plaster room The assistant who has worked in front of the patient throughout the entire procedure places his hands flat on the thoracic wall just below the axilla to obtain a well defined impression of this region The patient s arms are lowered until the shoulders are in natural position Drawn up shoulders should be carefully avoided The clavicles must be approximately horizontal Plaster of Paris splints are now placed over the shoulders following a course similar to the direction that suspenders might take Quick work is essential to achieve a homogeneous cast and complete union of the shoulder turns with the horizontal turns which encircle the thorax up to the axilla The plaster must be rubbed in carefully, particularly in front as it frequently happens that the completed negative breaks or separates in layers just below the clavicles thereby spoiling this important landmark for the proper location of the infraclavicular pressure pads (for the passive supporting spinal brace) When the cast is completed the surgeon or the second assistant will model the plaster of Paris carefully to the supra and infraclavicular spaces the infraclavicular space being of greater importance

Three or four minutes after the last bandage has been applied traction suspension may be terminated without danger to the model and the patient may be placed on a stretcher lying on his back Naturally the patient must be completely passive and relaxed when shifted from the vertical to the horizontal position Placed on his back he has ample time to recover from the considerable strain he has endured even under moderate traction suspension

As soon as the cast is set to such an extent that it cannot change its form we prepare to remove it The mold has to be cut in the midline of the body in front and on the dorsum of one shoulder about an inch anterior to the frontal plane of the body To close the mold in the correct position transverse lines are drawn with indelible pencil across the two cutting lines To secure the utmost comfort for the patient, we have introduced the rest on the stretcher for the final setting of the cast and the cutting instead of keeping the patient in the upright position throughout the entire procedure After the cast is cut with the Stryker electric cast cutter the edges will spread If the cast has not dried sufficiently to be removed at once we hold it in place by means of a few turns of a gauze or flannel bandage especially around the waist As soon as the cast is dry the patient is returned to the vertical position If he is paralyzed and unable to stand on his legs he

is again placed in the suspension frame The gauze or flannel bandage is cut

To separate the cast from the body the flat hand is carefully inserted between cast and body or between stockinette and body if a stockinette shirt has been used The pelvic strap has been previously cut together with the cast The patient is then told how to co operate when the cast is removed First the arm on the side of the cut over the shoulder is raised out of the cast then the body cast is turned around its longitudinal axis until the opening in front is situated on the side of the patient where the arm is raised The cast is then drawn away from the patient who pulls the other arm out of the armhole of the cast Immediately after the cast is removed from the patient it is returned to its original position by joining the cut edges according to the indelible pencil lines in the front and at the shoulder and closed by means of plaster bandages which have been prepared by the plaster room nurse Finally the stockinette shirt is taken out of the cast and the cast is removed to a dry place for complete setting

When the negative mold for a spinal brace has sufficiently hardened to retain its shape in every detail it is sent to the plaster room of the workshop for casting For this type of cast which requires large amounts of plaster a poorer quality plaster such as gray plaster of Paris may be used If economy is desired the center of the body cast may be filled with a wooden or steel core or with other mate rials such as small pieces of crushed dis carded models The landmarks which should be clearly visible on the entire surface of the mold are reinforced with indelible pencil in order to guarantee an exact copy on the posi tive models It is important to place the mold correctly on a sturdy table with an even sur face A spirit level may be used to advan tage to control the horizontal position of the pelvis from the very beginning If necessary the distal edges of the cast may be trimmed for this purpose The form is then filled with the necessary amount of plaster of Paris cream and left alone until the positive model is completely dry The negative mold is then removed by cutting along the lines of the previous cuts supplemented if necessary by additional incisions

A properly made cast renders correction of the model almost superfluous Only the iliac crests must be exaggerated with a chisel to secure the proper slant for this section of the pelvic frame In cases of marked deform ities the model may be further shaped To increase the pressure of the brace on a prom inent part of the thoracic wall in a severe sco liosis plaster of Paris has to be removed with

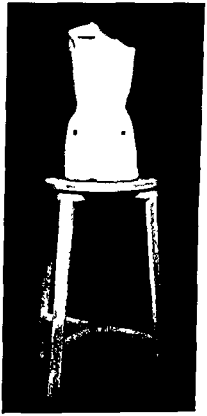


FIG 8 The positive model for a spinal brace on the swivel table

the aid of a drawknife The few corrections which are permitted on the positive model should be made by the orthopedic surgeon or at least under his immediate supervision Too much correction of the model is worse than

too little. After the model is finished with a little plaster of Paris cream or with sand paper, the landmarks are again reinforced with indelible pencil and the model is removed to the brace shop for construction of the brace.

A PLASTER OF PARIS MODEL FOR A CELLULOID OR FIBERGLASS APPLIANCE FOR THE BACK

A plaster of Paris model for a celluloid or fiberglass appliance for the back used to immobilize the spine in a recumbent position in the treatment of spinal injuries and diseases is made in much the same way as the *plaster of Paris shell for the back* which today is rarely used. The technique for making this appliance varies slightly in accordance with the outline required for the individual case. In some instances, the site of the lesion demands that the model be made with a head piece, while in others a support for the thighs or both legs must be included. Further variations in technique are related to the finishing of the appliance. For some cases the model may be converted into a plaster of Paris bed and completed immediately with a minimum of labor at the brace shop. Other cases demanding the use of a plaster of Paris bed over a longer period of time will require an appliance with a removable and washable lining. While many features must be considered for the individual case, I shall outline the procedure for making a plaster of Paris model for an appliance for a lumbodorsal lesion of the spine.

Position of the Patient

The patient lies on his abdomen upon a solid table. The pelvis and the proximal end of the sternum are supported by large sand bags. This is essential to obtain a certain degree of flexion at the hip joints and to correct, as far as possible the kyphosis of the spine, while attempting to bring the entire spine, the buttocks, and the head, if this should be included, into the same horizontal plane. The

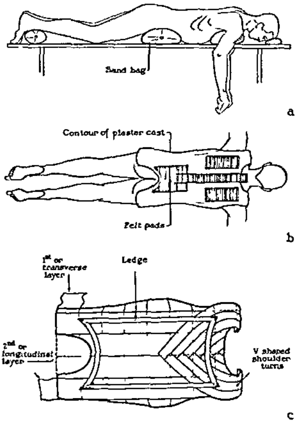


FIG. 9. The plaster of Paris shell. (a) Position of patient. (b) Contour of plaster cast and position of felt pads. (c) Placement of plaster of Paris turns and reinforcements in the various layers.

arms are abducted 90° at the shoulder joints to rest in the frontal plane of the body, or slightly ventral to it. A small pillow or sand bag under the forehead guarantees quiet breathing without the necessity for turning the head to one side. Gentle traction may be applied to the legs and the head to insure a straight position. Pillows and sandbags are not necessary, however, if a modern fracture table is available with its many adjustments for the position of the patient. The technique differs, of course, if the appliance is intended to correct an asymmetrical deformity, such as a scoliosis.

Preparation of the Back

If stockinette is to be used, a stockinette shirt with holes for the arms is put on the patient before he is placed on the table. His

hair is covered with a cap, such as is used in the operating room, or with a piece of stockinette If there is a large amount of axillary hair, this should be shaved or, in rare instances, covered with vaseline, although I generally oppose the use of any greasy substance in connection with plaster work A strip of white felt, 1 or 2 inches wide, and ¼ inch thick, is glued to the skin along the entire length of the spine, covering the spinous processes For a very thin patient, it may be necessary to place additional squares of felt over the sacrum and possibly over the scapulae The patient is then ready for application of the plaster

Application of the Plaster of Paris

Various modifications of plaster of Paris technique may be used when one is making a plaster model The method selected depends, to a large extent, on the patient's size and condition, and on the indications for the final appliance The plaster of Paris model may be made from single bandages of various sizes These may be reinforced by "splints" or "reinforcements," made from plaster of Paris bandages, or the entire model may be made in one piece from a large plaster of Paris sheet prepared from gauze and other materials soaked in plaster of Paris cream The latter technique requires better team work and greater experience in plaster of Paris work It has the advantage of being more rapid and may therefore be used for very young patients who are difficult to keep in the prone position until the plaster of Paris model is finished The standard procedure, however, makes use of 6-inch plaster of Paris bandages, supplemented by 10 inch bandages, and reinforced by splints and, finally, by plaster of Paris "ledges"

For a plaster of Paris model, a large number of bandages will be used with the patient's size determining the exact number This will include six to fifteen 6 inch bandages and five 10 inch bandages The preparation of a homogeneous cast calls for expert technique on the part of the plaster room nurse As mentioned earlier, a movable stand with water buckets is highly efficient After six bandages have been soaked in each bucket, the water is changed Fairly fast setting is required as little modeling is necessary In addition to the plaster room nurse, at least two assistants should be available, one to assist the surgeon apply and unroll the bandages, the other to rub in and mold the plaster Two bandages at a time are immersed in the water and the excess water is expressed into the waste water bucket, as described on pages 7 8 The surgeon and his assistant stand at opposite sides of the table at the level of the patient's pelvis The bandages are rolled off, back and forth, in a transverse direction, beginning at the trochanter of one side and ending at the trochanter of the opposite side It is important that the bandages cover the entire body from the surface of the table on one side to the surface of the table on the opposite side in order to secure a high border for the appliance The lateral borders or walls of the appliance are of great importance and must be quite strong in cases where a correction in the frontal plane of the body is desired About four layers of bandages are required in the horizontal direction as a basis for the shell In unrolling one bandage after another, the body is gradually covered up to the shoulders By the time the region of the axilla is reached, the plaster at the pelvis will have begun to harden At this stage, the other assistant will have to maintain constant, equal pressure with the flat of both hands (not with the tips of the fingers) on the lateral aspects of the pelvis to mold the plaster well over the trochanter and the iliac crest When the entire back is covered up to the axillae with about four layers of plaster of Paris bandages, the assistant will exert pressure with both hands against the lateral wall of the thorax, well up to the axillae The surgeon will then proceed to cover the neck and the cranial aspect of the shoulders in a similar manner For the latter purpose, the bandages will be unrolled in a V-shaped system of layers covering both shoulders down to the clavicle

with the point of the V at the spine, similar to the appearance of the V neck of a sweater While one assistant holds the cast in the axillae, the second assistant models the plaster of Paris over the shoulders In this model, without a head piece, the cut out for the neck will be well rounded, leaving sufficient freedom for the cervical spine so that a small pillow may later be placed under the head The entire procedure up to this point is accomplished in almost less time than it takes to read this description, and the plaster will cover the whole body at an early stage of setting permitting homogeneous union with each successive layer The horizontal or transverse layers will then be reinforced by longitudinal or vertical layers that run through the entire length of the cast and are carefully molded over the shoulders down to the table but which leave, at the same time sufficient space at the distal end where the cast will have to be trimmed for the use of a bed pan For a large plaster of Paris model, "splints" or "strengtheners" will be used, which will have been prepared in advance to be available to the surgeon as soon as the transverse or horizontal layers have been placed A 'strengthener," made of a 6 inch bandage, is applied fairly moist Placing of the "strengthener" is a matter of experience and depends largely on the purpose of the model Generally, it is important to reinforce the edges of the model particularly the two lateral borders at the distal end As soon as a number of "strengtheners" (normally four to six) have been applied and are thoroughly united with the first horizontal layers by painstaking modeling and massaging the cast is finished with a thin, external layer of horizontal or transverse turns It may then be advisable to reinforce the model further by means of "ledges" made of single plaster of Paris bandages The best way to make these is to drop a soaked and prepared bandage to the floor, holding one end up and then pulling up strips of equal length and winding them together until a plaster of Paris strip as thick as the thumb and of the desired length is obtained This is easily molded into the triangular "ledge" or crest which is to reinforce the model While this model is setting, a little plaster cream may be spread over its entire surface to give it a smooth appearance It then remains in place until it is completely set Not until this point may the pressure be released from the sides or lateral borders of the model Finally, the model may be removed This is accomplished by lifting it carefully at both ends at the same time The stockinette shirt (if used) is then cut

THE QUENGEL CAST

The Quengel cast is an excellent example of cooperation between orthopedic surgeon and bracemaker in the plaster room While *the surgeon applies the cast the bracemaker* furnishes the hardware consisting of simple hinges, subluxation hinges and aluminum posts which are needed to introduce the cor*rective forces of the Quengel*

The Quengel method was first outlined by F Mommsen in 1922 in a paper entitled, 'Die Dauerwirkung kleiner Krafte bei der Kontrakturbehandlung (*Quengelmethode*)" ("Continuous Action of Small Forces in the Treatment of Contractures") It was offered as a method of correcting a contracture over a long period of time, using *subliminal forces which act un*interruptedly but which are not so pronounced as to cause pain and muscle spasm The chief *obstacle to the correction of contractures consists in reflex spasm of the muscles involved* This may be overcome by the use of general anesthesia for forceful breaking or gentle stretching of adhesions Quick breaking of *adhesions is not only dangerous for poor risk* patients and impossible with hemophilia, but the method also contains the seeds of the very condition it seeks to correct Almost without exception, gentle manipulation under anesthesia has become a lost art

On the other hand, if the limb being treated is immobilized in a well molded plaster of *Paris cast to eliminate undue play and if a* corrective force acts uninterruptedly at the right place and in the right direction, the con

tracture will gradually give way and the soft tissue structures which constitute the contracture of a joint will rearrange themselves according to the desired position

When planning the Quengel treatment, the contracture or deformity being treated has to be thoroughly analyzed to find out the mechanical problem presented by each individual case It is most important to determine the location of the axis around which the movement of the joint will have to take place and the interrelationship of the forces to be applied at this axis In calculating the extent of the problem not only the natural axis of the joint and the position of the articular space must be considered but also the fact that in contractures and fibrous ankyloses adhesions within the joint will change the mechanical relations of axis and levers once correction is attempted For instance in correcting a flexion deformity of the knee joint in which adhesions have formed the lower leg will not rotate around the natural axis at the knee joint situated at the level of the femoral epicondyles but around an axis within the articular space (von Baeyer) Moreover in treating the flexion contracture of a knee joint we have to realize that we are dealing not only with a simple flexion deformity but also with a posterior displacement or subluxation of the tibia in its relation to the longitudinal axis of the femur To straighten the knee joint without prior determination of the axis around which the movements occur means that we may correct the flexion deformity but at the same time we increase a subluxation at the tibia thus adding a second deformity to the one already present

Mommsen originated the use of a "Quengel" as the best means of applying a subliminal force The so-called Quengel is a short stick or toggle used for winding or twisting two cords thereby gradually shortening their length This Quengel has been most satisfactorily used in the treatment of contractures and deformities due to infantile paralysis in an era when surgery was not as

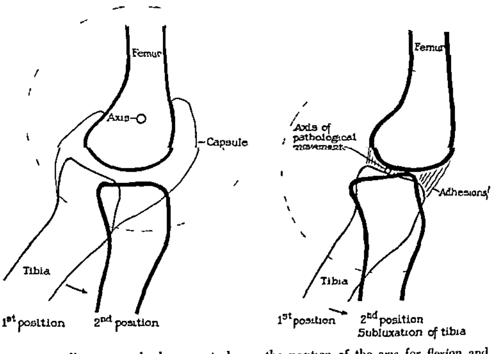


Fig 10 Adhesions in the knee joint change the position of the axis for flexion and extension risk of subluxation of tibia

freely employed as it is today. Personal experience with the Quengel method and its modifications since 1922 suggested its adaptation for the treatment of deformities and contractures in hemophilic arthropathies in 1946 After application of 120 Quengel casts in the treatment of hemophilia patients, I still consider the Quengel the simplest and most effective method and the one permitting closest control of corrective treatment

The principle of the Quengel method is applicable to flexion contractures of upper and lower extremities, and the plaster of Paris technique is much the same for all articulations lending themselves to this method It is most frequently used for the knee joint in cases with flexion contractures of as much as 90°, with or without posterior subluxation of the tibia The Quengel cast is not indicated if the flexion contracture amounts to less than 30° (AGE 150°)

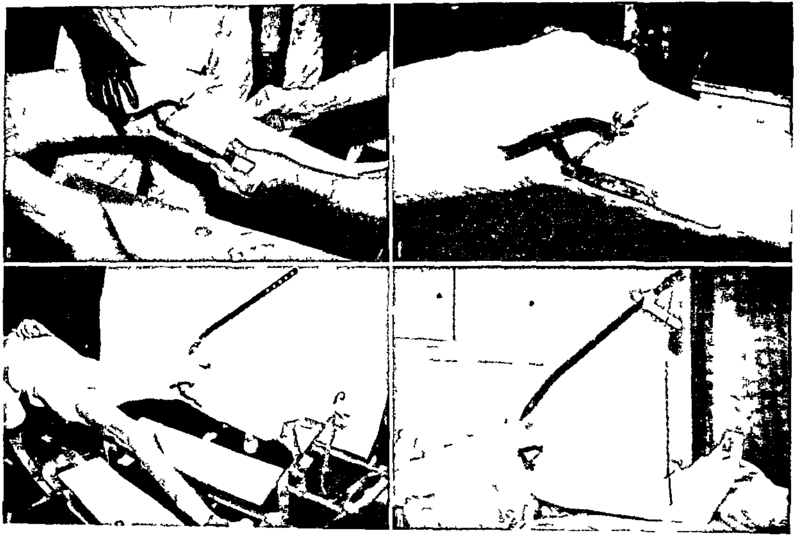
Properly applied, the Quengel method guarantees results that almost defy belief, even in cases of marked and long standing deformities To describe the technique for application of a Quengel cast, we will follow the procedure used in the case of a fifteen year-old hemophilia patient requiring application of a Quengel plaster of Paris hip spica for correction of a flexion deformity of the left knee with restriction of extension to 140° and a very marked posterior subluxation of the tibia

Prepared for treatment, the patient is placed on a table with pelvic rests, in this case on a Roger Anderson fracture table, with both feet attached to the foot section of the table in the usual manner A stockinette left hip spica is used to protect the skin and to hold the padding at the open ends of the cast Every attempt is made to support the patient at all points in the most comfortable manner by rubber pads to keep him relaxed while the cast is being applied All preparations for padding and casting, as well as for incorporation of hardware, are made prior to the start of the procedure to shorten the patient's time on the fracture table The fastest setting plaster of Paris (two to four minutes) is used and, as far as possible, applied in splints

The Quengel cast is applied in two sections the hip spica extending from the lower thorax aperture to the knee joint and the below-the-knee section, including lower-leg, ankle, and foot When applying the plaster of Paris, the knee joint is held in a painless position without trying to correct any part of the deformity Padding is applied from the thoracic cage down to the ankle, while padding for the foot section has to be postponed until the foot can be released from the straps holding it to the fracture table During the procedure, points of maximum pressure, such as the dorsum of the thigh from patella to the groin and the entire posterior aspect of the lower leg, are padded with foam rubber This is covered with turns of sheet wadding Ample sheet wadding must be used on the lateral aspects of the femoral condyles and particularly over the head of the fibula A "dinner pad," which is a small sheet or two towels folded together, is placed under the stockinette in the abdominal midline, to be withdrawn later for greater comfort whenever the patient eats When the padding is completed and held in place by turns of crepe paper bandages the cast is applied from the lower ribs down to the knee and, at the same time, from the knee to the ankle, leaving a small gap between the two casts at the knee joint As soon as the cast is rigid, the subluxation hinges are fitted by the bracemaker These hinges are specially designed to permit simultaneous correction of the posterior subluxation of the tibia by tightening two wing nuts on either side of the knee, while the Quengel itself works to straighten the flexion contracture

Proper placement of hinges is of the greatest importance for the desired result First of all, there must be neither shearing forces nor incongruence between the hardware and the anatomical axis around which the corrective movement occurs If simple hinges are used instead of subluxation hinges, as is permissible in cases where the subluxation is of minor importance or of very small degree,

Fig 11 Application of Quengel cast hip spica for flexion contracture at left knee with marked posterior subluxation of tibia Recurrent hemorrhages after initial satisfactory correction occurred because orthopedic appliance became ineffective (a) Patient age fifteen on Roger Anderson fracture table stockinette hip spica is applied (b) Application of felt and foam rubber padding to pelvis dorsum of thigh and posterior aspect of lower leg (c) Completion of padding with sheet wadding held in place by crepe



paper bandages (d) Plaster of Paris hip spica is applied to left lower extremity including foot Subluxation hinges and post for Quengel are seen on right leg section of fracture table (e) Subluxation hinges are carefully fitted to correct axis position (f) Subluxation hinges are incorporated into cast (g) The post for the Quengel is incorporated on dorsum of left knee (h) Quengel in action

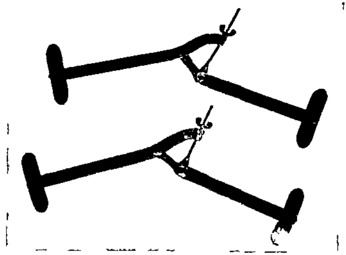


Fig 12 Subluxation hinges for Quengel cast

one can obtain some distraction at the knee joint and anterior shift of the tibia during extension of the knee by placing the hinges slightly anterior and distal to the anatomical knee joint axis which is at the level of the internal and external epicondyles of the femur

In the case under discussion subluxation hinges were used The proximal joints of these hinges are placed exactly at the axis of knee joint motion that is at the level of the internal and external epicondyles which are palpable through the padding It is necessary to mark these two points for the proximal joints of the hinges on the cast with indelible pencil *To obtain correct placement of the hardware* it is useful to use a tape measure to make sure that the thigh sections of the two metal hinges are at the same distance from the dorsal midline In very difficult cases it is advisable to determine with a lateral x ray film the correct site for the hinge using metal thumb tacks on either side of the cast The distal joint of the subluxation hinge is used to bring the tibia forward while the knee is being extended The wing nut screws are opened to give the maximum distance between the distal hinge of the appliance and the wing nut Holding the hinge in this position the lower leg section of the hardware is placed in the long axis of the tibia and marked off on the cast with indelible pencil again using a tape measure to insure equal distance from the dorsal midline for both hinges The hinges must be parallel to each other to work in exactly the same plane Using bending irons to adjust the thigh and lower leg sections to conform to the contour of the cast care must be taken to have sufficient space between the hinges and the knee and to keep the hinges parallel in the sagittal plane This can be accomplished by placing some plaster of Paris between the metal and the already rigid cast when incorporating the hinges by turns of plaster of Paris bandages Once the *location of the subluxation hinges in relation* to the cast and to the knee joint is established the most difficult phase of application of a Quengel cast has been accomplished

As soon as the hinges are secure the aluminum post to which the Quengel will be attached is incorporated in the dorsal midline above the knee with the length of the post corresponding to the length of the leg below the knee This means that a circle drawn around the center of the proximal hinge of the hardware would go through the heel of the foot as well as through the end of the aluminum post When adding the aluminum post to the dorsum of the thigh section of the hip spica it is advisable to place a few

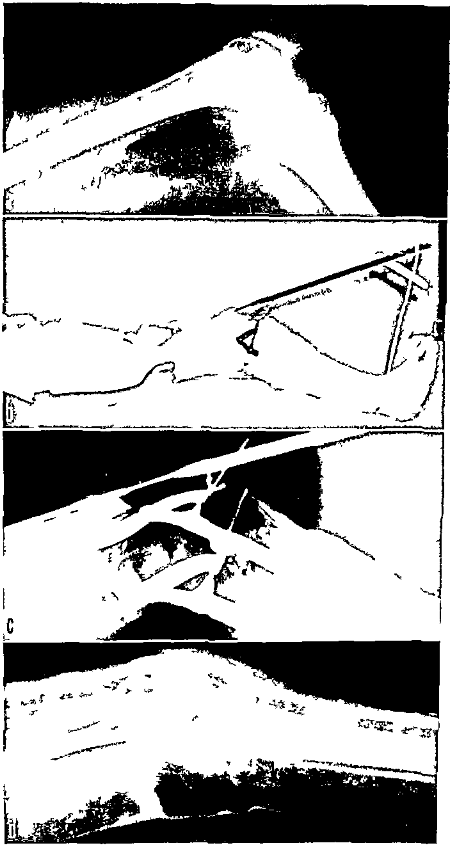


Fig 13 Advanced hemophilic arthropathy at right knee with typical deformity of patella and with posterior subluxation of tibia (a) Lateral x ray film with knee in maximum extension prior to correction (b) Quengel cast with subluxation hinges at the knee in action (c) X ray control of progress of correction in Quengel cast (d) Maintenance cast applied after partial correction was obtained

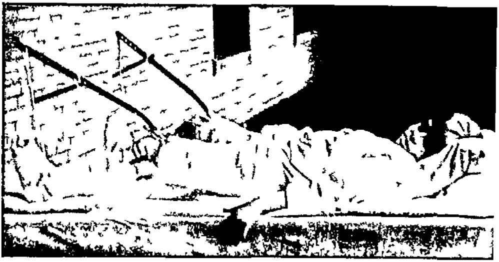


FIG 14 Patient age 10 requires Quengel cast double hip spica for simultaneous correction of flexion contractures at right and left knee in the presence of moderate hemophilic arthropathies No need for subluxation hinges

turns of plaster of Paris bandages around the proximal end of the post to insure better contact and more rigid incorporation into the already rigid hip spica

Before the foot is released from the fracture table all sections of the cast must be properly supported to eliminate premature extension of the knee joint by gravity The foot and ankle section is padded in exactly the same manner as the rest of the cast using a foam rubber pad on the posterior aspect of the heel and throughout the sole of the foot reaching slightly beyond the toes After the padding is completed and held in place by crepe paper bandages the cast is finished by adding the foot section with the ankle held at approximately 90°

The stockinette at the proximal margin of the hip spica and at the toes is turned down and held in place with a few turns of plaster of Paris The cast is now complete

After it is entirely rigid a cord is placed around the heel section of the cast and connected to one of the holes drilled into the distal end of the aluminum post The type of cord used on window shades or venetian blinds is most suitable for this purpose The cord is secured around the center of the heel section of the cast by a few turns of adhesive tape fastened onto itself to keep the cord from sliding The cord is tied to the post without undue tension Correction starts by turning the wing nuts of the subluxation hinges at either side of the knee as tolerated Once the initial setting has been made it is usually possible to turn the wing nuts one full turn each day securing their position by small strips of adhesive tape About twenty four hours after correction of the posterior subluxation of the tibia has been started the Quengel or short stick is placed between the cords close to the distal end of the aluminum post One or two tongue depressors are suitable for this purpose By turning the short stick or Quengel once in twenty four hours for one half or even for a full turn as tolerated correction of the flexion contracture is accomplished The tongue depressor is secured in place by strips of adhesive tape on the aluminum post as well as at the cord

Starting correction of the deformity by turning the wing nuts of the subluxation hinges and by tightening the cord with the Quengel tongue depressor one must keep in mind that we are trying to correct a contrac

ture the slow way by introducing subliminal forces only It would be easy to turn the Quengel more than once a day and patients, frequently impatient, try to speed up correction by interfering with the carefully planned timing The cords of the Quengel should always appear quite relaxed This is difficult to convey to most patients, nurses, and doctors They should never be as taut as the strings of a violin Although the cords are as relaxed as a sail on a sail boat when no wind is blowing they nevertheless accomplish the correction almost miraculously without causing pain, discomfort, or the risk of a hemorrhage in a hemophilia patient This slow correction permits all soft tissues involved such as the vessels and nerves in the popliteal region of the knee joint, to adjust themselves gradually to the changing position If the correction with Quengel and subluxation hinges is properly timed, there will be no setback If the speed of correction is greater than the patient can tolerate there will be a setback with valuable time lost

Chapter 2

SPINAL BRACES

Among the orthopedic appliances routinely manufactured in an active brace shop, a large proportion is designed for treatment of pathological conditions of the spine and merit special attention for several reasons. First, they are some of the most frequently prescribed orthopedic appliances, and the reputation of a brace shop will depend, to a large extent, on the quality of the spinal brace which it produces. Second, building an effective spinal brace constitutes a difficult mechanical problem, demanding intuition, constructive thought, and careful appraisal of the requirements of the individual case. Third, there must be skillful use of materials which have been selected to withstand an unusual amount of torsion and shearing, as well as bending forces. Rarely is each of these prerequisites for superior bracemaking fulfilled. Daily experience reveals how few braces, *worn for the various disorders of the spine,* are efficient and, at the same time, designed to permit the patient to participate fully in activities he should be able to enjoy. This underlines the urgent need for improvement in the manufacture of spinal braces.

Seeking a suitable classification of spinal appliances to simplify our discussion of construction principles, we might approach the problem from the medical point of view and classify spinal braces according to different diagnoses, such as spondylitis tuberculosa, spondylarthritis ankylopoetica, juvenile dorsal kyphosis, scolioses that are of varying degrees and are caused by various diseases, and so on. From the mechanical point of view, we might classify spinal braces as small and large, light and heavy, flexible and rigid. Considering the material used, we might also speak of corsets made of coutil and webbing with whalebones, of appliances made of leather, celluloid, or fiberglass, or of rigid braces using steel or aluminum.

Diagnostic criteria are considered in establishing the medical indication for a spinal brace, while the mechanical aspect chiefly concerns the bracemaker who suggests the material suitable for the brace prescribed by the surgeon. None of these classifications, however, gives an indication of basic construction principles.

After studying the problem from every angle, I found that certain requirements exist for every type of appliance which affords effective fixation, immobilization, unweighting, *or correction of the spinal column.* While these basic principles should be common to all spinal braces, the individualized aspects *of these appliances will vary according to the* purpose of the brace. The resulting types may be readily classified into two major groups which are characterized respectively by the principles of support and of correction. The first is the passive supporting spinal brace in which the chief action of the appliance is support, the second is the active correcting brace which serves primarily as a means of correction of a deformity or a defective posture. The first type, of course, may correct in addition to giving support, while the second group supports to a certain extent while it corrects. This classification has simplified the teaching and understanding of the construction principles for spinal braces and, over the past twenty-five years, has led to higher standards of work in the brace shop.

In our discussion of the construction principles for the two groups of spinal braces, we shall describe first the factors which are common to both and then the therapeutic and the mechanical action of each individual group

COMMON FACTORS IN THE CONSTRUCTION OF SPINAL BRACES

The construction of a spinal brace should never be based upon a routine prescription to the bracemaker Although I frequently stress the point that a certain standardization of work is essential to the proper functioning of a brace shop a spinal brace must be "custom made" It requires valuable materials and considerable labor, both of which make it expensive to produce The patient s psychological well being the course of his disease, and the degree of his disability will largely depend on the efficacy of the brace and *the comfort and freedom for action provided by it* As each individual case differs in physical constitution, medical condition social requirements, and professional activities the manufacture of a spinal brace demands careful medical indication and individualized construction Our basic designs for the passive supporting and active correcting spinal braces allow sufficient variation to satisfy the requirements of the individual patient

A correct plaster of Paris cast is the essen*tial basis for an effective brace* *Before we* proceed, however, to make the plaster of Paris mold for a spinal brace, we must make sure that the patient is ready for a portative apparatus and that his general condition will permit this somewhat strenuous procedure *Here, we must stress the fact that certain sig*nificant conditions may have been overlooked Occasionally, a spinal brace of the passive supporting type seems to be indicated for the support and correction of a deformity of the spine which is not a true deformity This may be a case of postural scoliosis caused by pelvic obliquity or the so-called "scoliosis sciatica," in which defective posture is caused by pain unrelated to the spine This occurs when unilateral spastic rigidity of the erector spinae muscles forces the spinal column into an abnormal curvature These conditions may be compared to the so called spastic or rigid flat foot where the equilibrium of the pronator and supinator muscle groups on the foot is seriously disturbed It would be just as great an error to make a plaster of Paris mold for a spinal brace in the presence of unilateral spasticity of the erector spinae muscles as it would be to take a plaster cast of a rigid flat foot The patient is ready for the plaster cast only if his muscles have been relaxed as far as possible by preliminary treatment

These considerations must also be borne in *mind if a spinal brace is to be constructed for* an old deformity, such as a long standing paralytic scoliosis In this case, preliminary treatment of the patient must include bed rest preferably on a Bradford frame, in order to attain maximum relaxation or stretching of contracted soft tissue structures prior to the making of the plaster of Paris model

Although the technique for making a plaster mold has been described in our first chapter the following six points bear repetition First, *the patient must stand upright, moderately* suspended Second the pelvis must be horizontal If one leg is shorter, a compensatory lift is necessary Third, the body must be equalized symmetrically in reference to a plumb line dropped through the center of the pelvis Care should be taken not to increase the lumbar lordosis For this purpose, the patient's feet must be anterior rather than posterior to the frontal plane of the body Fourth a pendulous or atonic abdomen must be supported by strapping before plaster of Paris is applied Fifth the deformity should not be overcorrected Sixth, the necessary landmarks must be distinctly outlined on the body with an indelible pencil In addition, landmarks for the pelvic frame should be indicated with a self modeling strap

A correct plaster of Paris mold renders correction of the positive model almost superfluous Only the iliac crests must be exagger

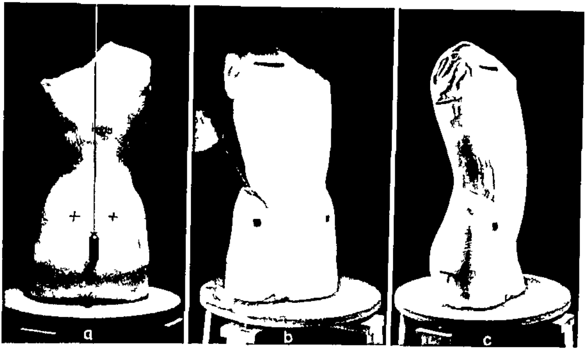


FIG 15 The positive model is prepared for a spinal brace (a) Back view model lined up with the plumb line (b) Iliac crests are exaggerated for the pelvic frame anterior superior spine and the clavicles are landmarked (The left shoulder is not shown) (c) Side view plaster is removed below the axilla in order to gain the correct position of the thoracic frame

ated by *excavation in order to give a proper* contour to the pelvic frame With the aid of level and plumb line the model is accurately placed on the turntable

Construction of a spinal brace of either type follows the principle of *a three point system of corrective forces* which form the essential basis for any effective orthopedic appliance Three main forces must be active and distributed over adequate surfaces or divided into a number of single units the sum of which is equal in degree and direction to the desired main or principal force necessary for correction

To support or unweight a diseased or "insufficient" spine or to correct a defective posture a brace must be rigid As far as the passive supporting brace is concerned it can unweight the spine relieve pressure from the diseased parts of the spine or substitute for paralyzed muscles only if it transmits the *weight to a region or part of the body which* is able to bear it Part of this action may be obtained by "reinforcing" the weak spine This can be accomplished by increasing the pressure within the abdominal cavity by bracing the thoracic cage or by maintaining the vertebral bodies in proper alignment to each other and in their proper relation to the central axis of gravity Such action might be exerted by a partly flexible appliance which makes use of tensile stresses This however would not suffice to take the weight off diseased or injured parts of the vertebral column nor to overcome the counteracting forces of contracted muscles and ligaments which have led to deformities such as a gibbus or a fixed scoliosis A rigid spinal brace properly constructed and well fitted brings more comfort to the patient than a flexible appliance which has to be tightened around the body in order to be effective For this reason I have discarded the

use of flexible constructions and have limited our production to rigid appliances

Bearing the three point system in mind, we begin our discussion of both types of brace construction with the pelvic frame To obtain the desired action on the body by means of an instrument which is mechanically sound, we must have a *fundament* to which the weight of the body may be transmitted and which serves as a basis for the forces correcting a deformity of the spine This is accomplished by the pelvic frame, which represents force number I in the three point system In addition, the pelvic frame holds the entire appliance in close contact with the moving body in every position, distributing the pressure of the great force required over a large area of the body

To fulfill these requirements, the frame must be stable in itself To gain a secure

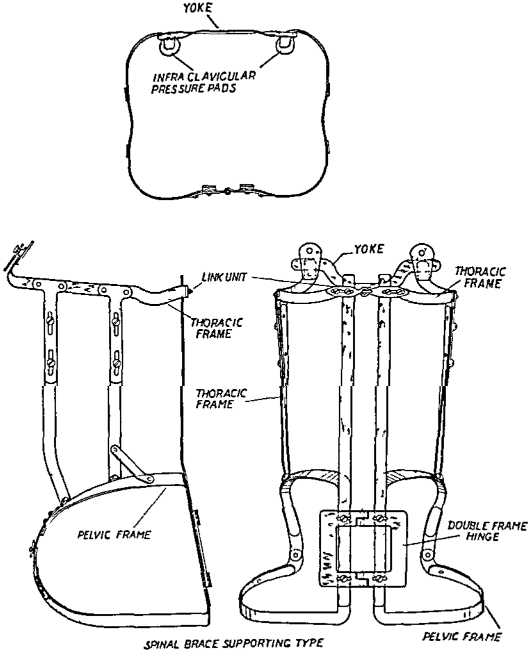


FIG 16 Working drawing for the steel skeleton of a passive supporting spinal brace

hold it must almost completely encircle the pelvis The upper section of the frame follows the contour of the iliac crests encircling the anterior superior spine of the pelvis in front while its lower section turns back just above the greater trochanter over the gluteal region to a point medial to the sacroiliac articulation A frame of this size cannot be made in one piece It is constructed in two halves connected by a hinge (or spring plate) which permits opening of the frame when applying or removing the brace The fact that the pelvic frame must be constructed in two parts connected by a hinge at the back will detract from its stability unless the hinge fulfills certain requirements Von Baeyer who originated this type of brace design solved the problem of stability of the pelvic frame by constructing a "double frame hinge" which materially added to its stability This hinge which is used with slight modifications in the passive supporting as well as in the active correcting spinal brace is wrought by hand of heavy surgical steel forming a rectangle three and one half inches in width and three inches in height It distributes the hinge action over more than half of the posterior height of the pelvic frame while at the same time strongly reinforcing the frame against torsion and shear The hinge is attached to the two halves of the frame by means of special screws with large heads and slots in the frame of the hinge which permit exact adjustment of the frame to the width of the pelvis particularly important for a growing individual The details of the hinge and its construction will be discussed in the technical part of this chapter

Occasionally it is permissible to substitute a rectangular plate of blue spring steel of the same size for a double frame hinge thereby saving weight and labor

If the pelvic frame correctly fits the plaster of Paris model it is fitted to the patient's body before we proceed with further construction of the brace This first fitting of the pelvic frame alone is of fundamental importance for the proper action of the entire appliance Its seat is therefore tested with the patient standing sitting walking and bending forward and sideways as far as his condition permits

Introduction of the remaining two forces of the three point system varies with the type of brace

THE PASSIVE SUPPORTING SPINAL BRACE

As the name implies the main purpose of this appliance is to support a weak or insufficient spine It is indicated whenever the spine requires support from without This may be necessary for the entire spinal column or for one or several of its elements

It is not necessary to make a distinction here as pathology of the greater part of the spinal column as well as a serious lesion of only one or two vertebral segments require support and immobilization of the entire spine For this reason we use only one type of passive supporting spinal brace Furthermore its size in relation to the body is always the same whether it is indicated for treatment of spondylitis ankylopoetica osteomalacia senile osteoporosis or for infectious disease or pathological fracture of one or two vertebral bodies

In addition to supporting unweighting and immobilizing the spinal column a passive supporting spinal brace permits the introduction of additional forces for the correction of deformities such as scoliosis and kyphosis In scoliosis we shall find that the active correcting spinal brace to be described later can be applied only in a limited number of cases where we are dealing with a flexible spine and a good musculature—prerequisites for the successful action of the corrective forces in this brace We have to resort to the supporting type of brace construction in a paralytic scoliosis where we aim at correction of the deformity but at the same time have to support the weight of the trunk by substituting the spinal brace for paralyzed muscles Such a brace is also indicated for severe scoliotic deformities with marked sec

ondary changes of the skeleton where the trunk is shifted to one side and hangs over the pelvis, with the thoracic cage sometimes forming what appears to resemble a balcony In these cases, where we cannot correct the scoliosis, we try to avoid a progression of the deformity and to relieve the patient from constant pain caused by intercostal neuralgia and pressure of the deformed skeleton on the internal organs

We are now ready to discuss the mechanical principles to be applied in building the pas sive supporting spinal brace

Complete immobilization of the spinal col umn cannot be accomplished by means of a spinal brace Unlike a bone graft in a spine fusion, a brace applied to the trunk cannot act directly on the elements of the spine proper It is impossible to eliminate a cer tain amount of play in the parts of the body which lie between the skin and the spine We cannot control, for instance, the effect on the vertebral bodies of breathing and the movements of the rib cage The fact that the most effective spinal brace will never completely immobilize a diseased section of the spine must be kept in mind when discus-sing the medical indication for a spinal brace in preference to a fusion operation Correc-tion of a deformity, however, and support of the spinal column or unweighting of diseased elements of the spine can be well accom-plished by means of a correct spinal brace

Attempting to unweight a diseased spine, one might be inclined to use traction This is frequently applied to the spine by means of a Glisson sling, which pulls on the head, but which is scarcely used as a portative ap-paratus with the exception of constructions designed for treating lesions of the cervical spine Another approach has been suspen-sion of the body weight by means of crutches fitted in the axillae Even now, we may see a brace construction derived partly from the old Hessing type of spinal brace in which the body weight seems to be suspended and transferred to the pelvis by means of crutches in the axillae It is hardly necessary to point out that such an appliance will cause considerable discomfort to the patient by pressure on vessels and nerves in the axillae With the shoulders drawn up in this arrange ment, at least part of the force to be applied is rendered ineffective

Studying the problem from the viewpoint of the mechanics involved, one learns that it

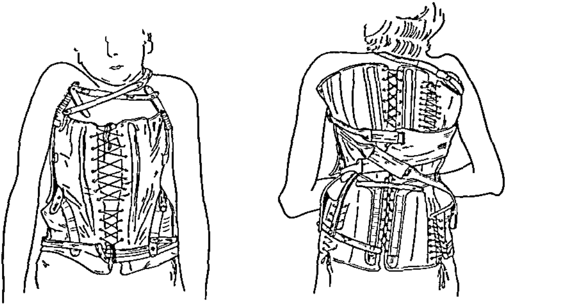


FIG 17 Old fashioned spinal brace suspends the patient at the axillae The shoulder girdle is drawn up to the head (Based on photographs from Hessing Hasslauer)

is impossible to apply an effective force to the spine by suspending the patient at the shoulder girdle It should be apparent that if traction is applied to both ends of a curved rod or a broken line with an obtuse angle, the resultant force produced to straighten out the angle will be very small, no matter how strong the pulling forces are This is demonstrated below by the parallelogram of forces It follows that traction is not the should be generally recognized that hyper extension of the spine must be used instead of traction

Just as our diagram illustrated how a curved rod or an angulated line must be straightened out by means of three forces, so we apply these forces to the patient's body, with two forces acting on the ventral aspect of the body and the third functioning dorsally at the site of the spinal lesion One of

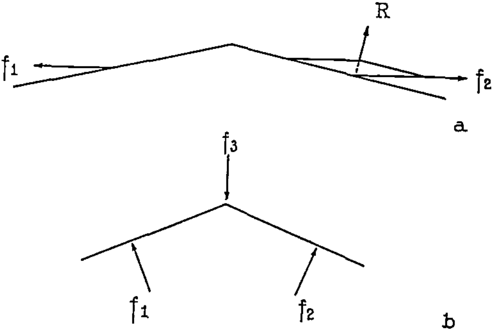


FIG 18 (a) Demonstrates that traction (provided by a Glisson sling) is ineffective for correction of a deformity forming an obtuse angle The parallelogram of forces shows that forces f 1 and f 2 have a small resultant R (b) The three point system with f 3 opposing f 1 and f 2 achieves the correction (Redrawn from Hans von Baeyer, *Grundlagen der orthopadischen Mechanik*, Berlin, 1935, courtesy Julius Springer)

proper means of correcting a curved or angular deformity of the spine If, however, three forces act on the broken line, with two of them perpendicular to the arms of the angle and a third on its vertex, it is simple to straighten out the angle to 180°, at which point the force acting at the vertex is equal to the two forces acting on the arms Such a three point system must consequently be applied in order to correct a deformed spine

These mechanical considerations have been confirmed by clinical experience, and it the two ventral forces is introduced at the pelvis and the other high up on the anterior thoracic wall The third force must oppose them in the back at a mid point between them yet not so high as to oppose the upper force in front only, thus rendering it ineffective In other words, Force I acts on the pelvis, Force II is exerted in the same direction anteriorly just below the level of the clavicles, Force III operates on the back, being placed low enough for the dorsal part of the spine above the site of the lesion to be

able to yield to the correcting force which acts on the thorax in front. This can be easily understood by studying the figures below. Various placements of a body cast or corset demonstrate that correction and hyperextension of the spine cannot be accomplished if no force acts high enough in front or if the cast or corset is made too high dorsally. This would render hyperextension of the spine impossible and the second force in front ineffective

thereby introducing the proximal effective force anteriorly. This is divided into two forces which act on either side below the clavicle by means of infraclavicular pressure pads. The thoracic section is a rigid steel frame which encircles the thorax laterally at a level of about one inch below the axilla. It is high in front with the pressure pads just below the clavicle and lower in back where it should have no mechanical action. The main purpose of the four uprights is to support the thoracic

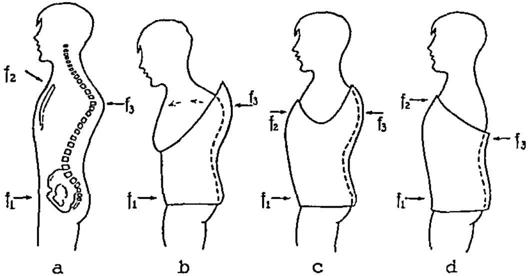


FIG 19 (a) The three point system of forces applied to the spine (b) Correction will not be obtained if f 2 is missing because the brace is too low in front (c) Correction also cannot be obtained if the brace is applied too high in the back with f 3 acting at the level of f 2 (d) Shows the correct outline

As this covers the chief mechanical principles underlying construction of a passive supporting spinal brace, we are now ready to describe how the three forces are applied in practice

Force I is exerted through the pelvic frame, which has already been discussed as the common factor for all spinal braces

Force II is exerted through the thoracic frame, which represents the force or the sum of forces acting on the thorax proper and not on the shoulder girdle. This frame consists of four uprights, two on either side of the trunk. These carry the thoracic section of the brace which encircles the upper part of the thorax, frame at the correct level and to fix its relation to the pelvic frame. The uprights follow the body contour closely without exerting undue pressure at any point. They guarantee the proper relation of the thoracic frame to the pelvic frame by means of one or two angle irons at each side which keep the angle between the posterior upright and the pelvic frame constant. These angle irons are indispensable for rendering Force II, on the anterior thoracic wall, effective. In order to make the thoracic section rigid, while at the same time allowing the appliance to be opened, there must be a hinge in the back corresponding to the hinge of the pelvic frame. A remov-

able yoke in front, extending from one infraclavicular pressure pad to the other, connects the thoracic frame The hinge is constructed as a link permitting motion of the two halves in all directions The four uprights connecting the pelvic frame with the thoracic section and fixing the position of the latter share, at the same time, the task of unweighting the spine and transmitting the weight to the pelvis This is not accomplished by providing axillary crutches which can act on the shoulder girdle only, but by gaining a hold on the lateral wall of the thoracic cage about an inch below the axilla For this purpose, the thoracic frame is made concave toward the thorax laterally between the two uprights Outlining our technique for making a plaster of Paris model for a spinal brace in the previous chapter, we paid particular attention to the lateral thoracic wall below the axilla where the plaster must be molded to the thoracic wall with great care On the positive model, it is sometimes necessary to remove plaster at this site to obtain the convex form of the thoracic frame

As a rule, two uprights, made of light spring steel, are added in the back, and screwed to the posterior vertical part of the pelvic frame between it and the double frame hinge as seen in the diagram While not connected with the thoracic frame they add, however, to the stability of the brace by maintaining the proper position of the fabric or webbing which constitutes Force III in the back

Thus far, we have seen that Forces I and II of the passive supporting spinal brace act on the body by means of a rigid steel construction The principal action of both forces operates on the pelvis and the upper part of the anterior thoracic wall in the antero posterior direction Force III opposes Forces I and II in the postero anterior direction, acting on the convexity of the dorsal spine To be effective, it must be adjustable As this force must be equal to the first two forces which are distributed over a considerable area of the body by means of the pelvic frame and the thoracic frame, it must exert its action over a still greater surface of the back It is introduced by a large rectangular piece of fabric (coutil or pekinstripe material) which extends from the pelvic frame almost up to the link unit of the thoracic frame, thereby distributing the pressure over as large an area of the back as possible The upper limit of the spinal pad is established by the level of the spinal lesion to be treated As already stated Force III may, under no circumstances, act at too high a level, as it would otherwise render Force II ineffective In a case in which bilateral symmetry of the spine is preserved, the posterior pressure pad extends laterally to about one inch lateral to the posterior flexible uprights made of spring steel The rectangular piece of fabric is fitted with whalebones in order to maintain its shape, and with approximately eight eyelets on each side which are no more than one inch apart Lacing attaches the posterior spinal pad to the two lateral parts of the corset which are cut of similar material and fitted with eyelets for lacing to the corresponding eyelets of the posterior medial part The two lateral parts of the corset are firmly attached to the anterior lateral rigid uprights If the lacing is tightened, Force III becomes active, pressing on the dorsal convexity of the spine and opposing the two anterior Forces I and II The lacing permits exact adjustment and an increase in the pressure as the spine yields to the correction

If the passive supporting spinal brace is used in the treatment of asymmetrical deformities of the spine, such as a paralytic scoliosis, the direction of Force III may be altered by cutting and attaching the fabric to the rigid steel construction according to the requirements of the individual case If, for example, a C shaped right lumbodorsal curvature is to be treated by the passive supporting type of spinal brace, the fabric representing Force III will be cut into two parts instead of three as is done in symmetrical cases Only one lacing will be required and, where a right convex curvature exists, this will be situated on the left side of the brace close to the posterior lateral rigid upright to which it will be

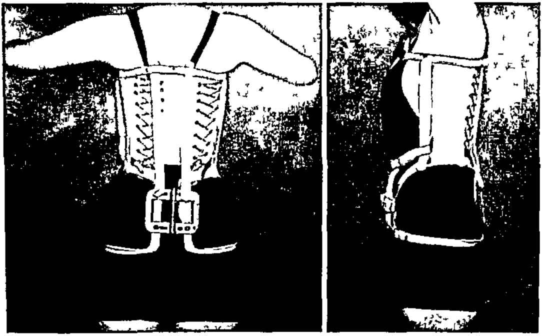


FIG 20 Passive supporting spinal brace with bilateral lacing

firmly attached The larger part of the corset will be firmly attached to the right anterior lateral rigid upright This gives Force III not only an opposing direction to Forces I and II, but also an effect on the curvature in a direction from right posterior to left anterior The situation becomes more complicated if we are dealing with an S shaped curvature of the lumbodorsal region In such a case, the fabric must be divided horizontally into an upper and a lower half, with each half being attached and laced separately according to the principle used for a C shaped or unilateral curvature

The brace is finally completed with a corset front or at least an abdominal pressure pad or apron According to the requirements of the individual case, we can close the entire corset in front by means of the same fabric used in the back with eyelets and lacing anteriorly For this part of the corset, a paper pattern is cut at the time of the second fitting, and the material is finally adjusted at a third fitting In the closed corset front, the fabric is firmly attached to both anterior lateral rigid uprights down to the pelvic frame as well as to the pelvic frame itself by means of lacing that follows the exact contour of the anterior part of the pelvic frame where it encircles the anterior superior spine The shape of the corset front is maintained by whalebones and reinforced at the distal end by one or two leather straps attached to studs on the pelvic frame In many instances, there is no need to use a closed corset front An abdominal pressure pad or apron reaching from the symphysis to the umbilicus and attached to the pelvic frame by means of two or three straps and buckles may suffice

The proper fitting and action of the brace should be checked by x ray taken with the patient standing

This passive supporting spinal brace, built according to construction principles described above and technical specifications to be discussed below, will fulfill the purpose of its indication by supporting the spine in the desired position without discomfort to the patient while, at the same time, correcting a deformity which may be present It will not interfere with the free use of the arms as it does not aim to support the body by means of

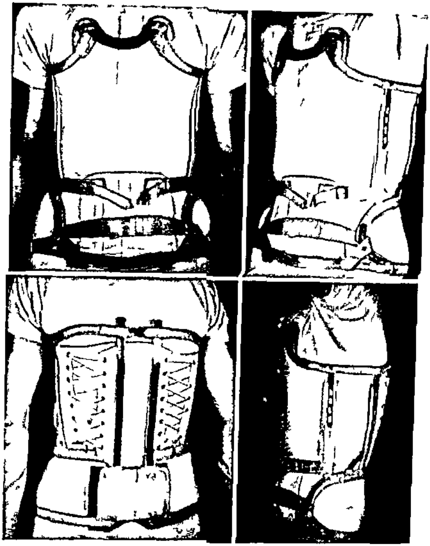


FIG 21 Passive supporting spinal brace with bilateral lacing and abdominal apron on patient with spondylitis ankylopoetica

axillary crutches It will not cause pressure sores as all forces are well distributed over a *sufficiently large area carefully avoiding bony* prominences such as the anterior superior spines The brace will fit close to the body follow its movements and remain effective in every position It will enable the patient to take part in all or many of his professional social or athletic activities according to the condition of his disease In no way will the patient be restricted in these activities by the mere fact that he is wearing a brace As a well fitted brace of this type has no tendency to "run away" from the body it will also be satisfactory from the cosmetic point of view

THE ACTIVE CORRECTING SPINAL BRACE

The construction principles for an active correcting spinal brace differ in many respects from those applied to the building of the passive supporting spinal brace Its use is limited to a rather small number of cases compared with the almost general applicability of the supporting type *Nevertheless the prin*

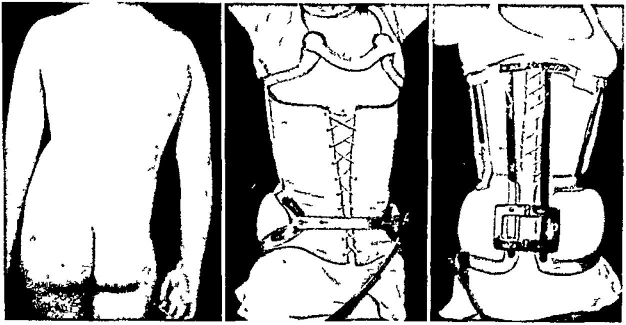


Fig 22 Passive supporting spinal brace with unilateral lacing in the back and perineal strap on the left side for treatment of a paralytic scoliosis

ciples underlying the construction of the active correcting spinal brace are of general interest in any discussion of individualized brace construction

We know that the passive supporting type of spinal brace covers almost every conceivable indication in the treatment of diseases and deformities of the spine which require not only support but also the action of corrective forces in the sagittal as well as in the frontal plane of the body Consequently, most cases representing a deformity of the spine in the frontal plane, such as a scoliosis, demand the rigid construction of the passive supporting spinal brace This is particularly true for the severe degrees of paralytic scoliosis which cannot respond with muscle action to corrective forces And in fixed deformities of the spine, we can scarcely obtain a correction in addition to the necessary support

There remains, however, one group of scolioses amenable to treatment by forces intro

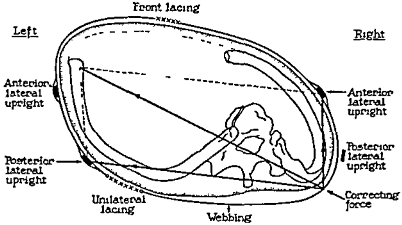


Fig 23 Corrective action of unilateral lacing in a passive supporting spinal brace for treatment of scoliosis

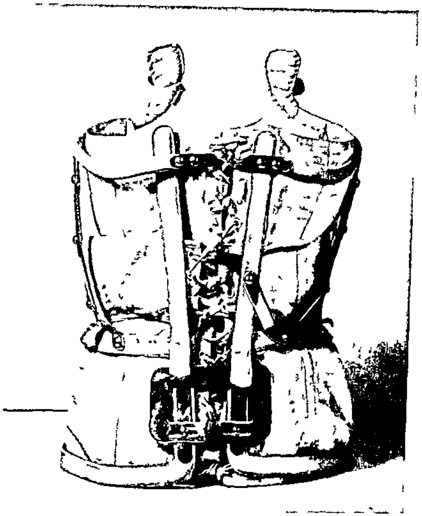


FIG 24 Passive supporting spinal brace for treatment of S shaped scoliosis The unilateral lacing is divided horizontally in order to introduce opposing forces on the curvature

duced by means of an active correcting brace Some of these may be borderline cases creating some doubt as to whether the deformity *of the spine is sufficient to warrant* a major orthopedic appliance or whether it would be possible or even better to attempt treatment of the defective posture by building up weak muscles and restoring the normal balance of the spine by means of exercises

Generally speaking the indication for an active correcting spinal brace is present in cases of a flexible deformity or defective posture of the spine (in the frontal plane of the *body), which cannot be effectively treated* without an orthopedic appliance but which do not require support and the introduction *of the strong corrective forces supplied only* by the supporting type of spinal brace

In analyzing a fully developed scoliosis a defective posture or deformity of the spine in the frontal plane, we find that the following three elements are responsible for the deformity, although not all three are present in every case (1) curvature of the spine in the frontal plane of the body, (2) shifting of the body in the frontal plane with regard to the pelvis,

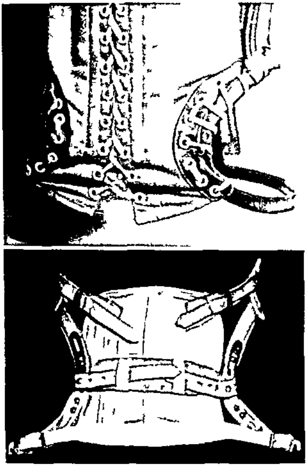


Fig 25 Passive supporting spinal brace (Top) Closed corset front attached to the pelvic frame by laces (Bottom) Abdominal apron with straps and buckles

(3) deformity of the thoracic cage caused by torsion of the spine

To correct the scoliosis, these three components require correction The third element torsion of the spine with the secondary deformity of the thoracic cage, is very difficult to correct In the cases suitable for treatment by means of an active correcting brace, we have to neglect this element of the deformity particularly since any attempt at correcting the torsion would require the introduction of forces acting on the thorax This, in turn, interferes with the freedom of the body, and this freedom, as we have stressed, is an important condition in cases where an active correcting spinal brace is indicated Moreover, the cases which are really suitable for treatment with this type of orthopedic appliance, usually present only a moderate degree of torsion

The curvature of the spine proper and the deviation or shifting of the trunk with regard to the pelvis, which represent the other two elements of the scoliosis, can be adequately treated with an active correcting spinal brace

Defining the term *active correcting* as it applies to the construction of the active correcting spinal brace, we should like to express the idea that the corrective forces of this appliance bring the trunk and the spine into such a position that the patient has to use

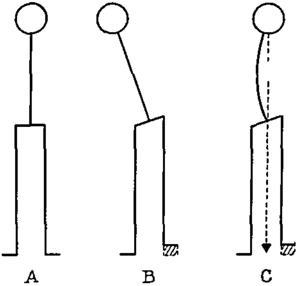


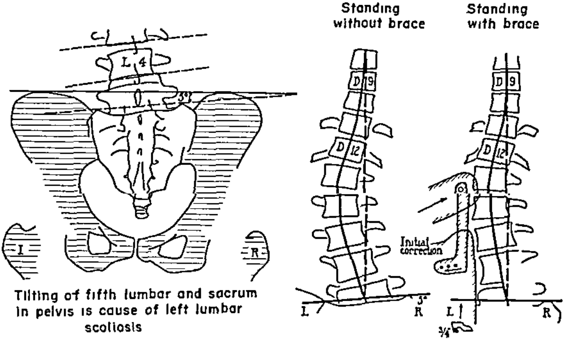
Fig 26 Influence of pelvic inclination on the spine (see text)

his active muscle power for the correction of the deformity In other words, the brace has an "indirect action" on the deformity

A simple example (Figure 26) will illustrate how an influence on the posture of the spine by active muscle action can be exerted by forces which act indirectly If a normal person stands erect with his weight equally distributed on both legs, the pelvis will be level and the spine straight and in the plumb line through its basis at the lumbosacral junction (A) If the right side of the pelvis is raised by a lift under the right foot without changing the straight

course of the spinal column, an inclination of the spine towards the left side would result, and the head would consequently be displaced toward the left (B) The desire to carry the head well balanced over the body's center of gravity, that is in the plumb line, induces a lateral curvature of the spine, a C shaped curve, convex toward the left side (C) In a similar way, we shall find that a case of a C-shaped scoliosis to the left may be the result of a congenital deformity at the lumbosacral junction or of the position of the fifth lumbar vertebra In this case, both legs are equally long and the pelvis is level, but the spine is based on a wedge or an inclined plane Attempting to carry the head in the plumb line of the body's center of gravity, the spine assumes a C shaped scoliosis convex toward the left side As there is, for anatomical reasons, very little lateral motion in the lumbar section of the spine, the deformity will occur at the lumbodorsal or the lower dorsal region The curvature will be fixed to a certain extent, depending on the degree of the deformity and on the patient's age and general condition If the left side of the pelvis is raised by a lift under the left shoe until the basis of the spine (the proximal surface of the fifth lumbar vertebra) is horizontal, the curvature of the spine will at first persist, with the head being shifted toward the right side, and the patient will use the activity of the muscle groups controlling the spine to bring the head back into normal position This would lead to a compensatory curve in the dorsal spine proximal to the primary curve as long as the latter is fixed If, however, the primary curve of the lumbodorsal section of the spine is more or less flexible, the curvature will be straightened out by active muscle power, causing only a moderate compensatory curve in the proximal section of the spine or eliminating it altogether

The simple procedure of changing the posi



a b

Fig 27 X ray tracings (a) Tilting of fifth lumbar vertebra and sacrum in the frame of the pelvis causes a left lumbar scoliosis (b) The heel of the left shoe is raised ¾ inch and an active correcting spinal brace is applied

tion of the pelvis with the object of stimulating the action of the spinal muscles to correct a simple curvature may be indicated in mild cases of postural scoliosis it is always necessary in addition to other corrective measures if the scoliosis is entirely or partly caused by a pelvic obliquity As a rule however it is not possible to influence the posture of the spine by changing the position of the pelvis The next step is to introduce forces which influence the relation of the trunk to the pelvis This is essential when the curvature of the spine is not compensated in itself but has led to a shifting of the thorax to one side adding the second element "the deviation (von Baeyer) to the first element "the curvature"

A deviation although usually secondary to the curvature of the spine proper may be discussed first because it is simpler to correct For this correction three forces are necessary to bring the spine and consequently the thorax into the correct bilateral symmetrical relation to the plumb line Theoretically two of these should act on the spine to straighten out the curvature responsible for the deviation The third force must act on the pelvis As the chief motion in the lumbar spine occurs in the sagittal plane of the body and there is marked resistance to lateral bending the force which should act on the lumbar spine may be transferred to the pelvis

To correct the curvature and deviation of a flexible spine by means of the hands it might appear possible to achieve the desired object with only two forces Von Baeyer however demonstrated that in this case also three forces must be active the third force being a so called "latent force" represented by the friction of the patient s feet on the ground In constructing an orthopedic appliance which is intended to correct the deviation two of the forces in the three point system must act on the pelvis and one on the spine at the apex of the curvature By shifting the center of gravity and consequently the equilibrium of the body the deformed spine is moved from a malposition in which it has been more

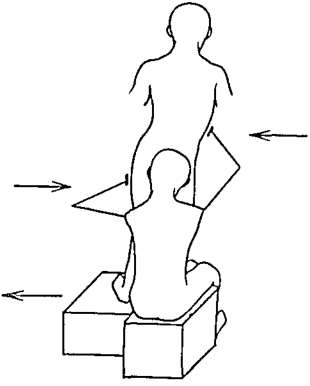


FIG 28 Two visible forces are applied for correction of a scoliosis by the surgeon s hands The third force a latent force" is presented by friction between the patient s feet and the ground (Hans von Baeyer *Grundlagen der orthopädischen Mechanik* Berlin 1935 courtesy Julius Springer)

or less balanced to a new position which stimulates and activates the muscles for the reasons mentioned above so that they will try to alter the position of the spine (the curvature) until a better alignment in the new position is obtained

Correction of the curvature of the spine proper the first element of a scoliosis presents a problem similar to the one present in correction of a knockknee a curved or angulated rod must be straightened out by means of three forces One of these must act on the apex or vertex of the angle and the other two on both ends of the arms of the angle The problem is more difficult in the case of the spine as it is not possible to introduce forces which act on the spinal column directly as they do on the leg In arranging the forces which must act on the spine in the

frontal plane in order to straighten the curvature the most important force which acts at the apex of the curve can be introduced only by means of transmission through the posterior section of the ribs It is therefore necessary to determine by x ray the rib which is connected with the vertebra at the apex and to apply the thoracic pressure pad which introduces this force at such a level (below the level of the vertebra) that the force will be effective in the direction of the posterior section of this rib Theoretically the two opposing forces effective on the concave side of the curvature should in the case of a simple dorsal curvature act on the cervical and lumbar spine In practice however this is impossible If the proximal force were to act on the cervical spine it would cause a compensatory curve rather than a straightening of the curvature being treated Therefore the proximal force has to act on the proximal ribs The distal or opposing force may be shifted to the pelvis for the reasons already discussed in order to correct the deviation A brace construction which makes use of these three forces for the correction of a spinal curvature is however no longer an active correcting brace and it would fail to stimulate the muscles to active correction

The active correcting spinal brace must introduce three forces in order to correct the deviation of the thorax in relation to the pelvis For a flexible spine this brace will at the same time effect a change in the position of the spinal column as an entity as well as in the relationships of its sections This will lead to straightening of the curvature and to realignment of the spine in reference to the center axis of gravity

To introduce the forces which should act on the spinal column and the thorax we must again have a *fundament* or basis on which we can build up these forces In other words we have to gain a secure hold on the pelvis As we have said before the pelvic frame represents Force I the most important element in every type of spinal brace One might assume that in an active correcting spinal brace with moderate forces acting on the spine and the thorax the construction of the pelvic frame could be lighter and less rigid than in the supporting type of brace This however is not the case

In the active correcting brace the forces which act on the spine have a tendency to rotate the pelvic frame in the frontal plane of the body If such a rotation occurs these forces become ineffective It is therefore necessary to introduce auxiliary forces which guarantee the position of the pelvic frame on the pelvis overcoming the rotatory forces which originate from the body s resistance to correction in the frontal plane Here we must mention the fact that the force acting on the curvature of the spine by means of the thoracic pressure pad is rigidly connected with the pelvic frame to form a solid unit of the three point system in a triangular arrangement

The pelvic frame for the active correcting spinal brace is built exactly to the specifications given at the beginning of this chapter where it was described as the basis of every spinal brace construction except for the following points

1 The lower horizontal bar of the double frame hinge carries on the side of the curvature an extension for the regulation of an adjusting arm which connects the thoracic pressure pad with the thoracic frame

2 For the same purpose the proximal horizontal bar of the pelvic frame on the side of the curvature is fitted with a pivot for the adjusting arm at the proximal posterior right angle of the pelvic frame

3 A perineal strap is attached to the distal or trochanteric horizontal bar of the pelvic frame on the side opposite the deformity in order to overcome the rotating force which tends to shift the pelvic frame upward on this side

4 A trochanteric pressure pad may be added for the same purpose on the side of the deformity

It is of prime importance that the pelvic frame rests securely over the iliac crests es

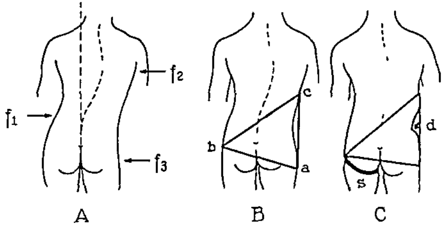


Fig 29 The introduction of the three point system in an active correcting spinal brace (A) Distribution of the three forces (B) The three forces are rigidly connected in a brace the appliance can rotate around points *a* or *b* (C) The perineal strap *s* prevents rotation around *a*, pressure at the right iliac crest *d* prevents rotation around *b* (Redrawn from Hans von Baeyer *Grundlagen der orthopadischen Mechanik*, Berlin 1935 courtesy Julius Springer)

pecially on the side of the curvature, in order to prevent a downward movement of the pelvic frame by rotatory as well as by vertical stresses

With the pelvic frame representing Force I, Force II may be a latent force, such as friction of the patient's feet on the ground, as shown by Figure 28 Frequently, however, as in cases requiring correction of the deviation, the pelvic frame contains a second force, opposing Force I

Force II is introduced by means of a thoracic pressure pad This acts on the apex of the spinal curve, introducing the force at a level below the vertebra at the apex, because of the direction of the ribs The thoracic pressure pad is connected with the pelvic frame on the side of the curvature by means of the adjusting arm in the back and a short supporting bar in front The thoracic pressure pad conforms to the shape of the thorax, and its longitudinal axis almost follows the course of the rib which transmits the force Placement of the thoracic pressure pad lower in front than in back allows more freedom to the anterior wall of the trunk and facilitates breathing and movements of the body While Force II is rigidly linked to the pelvic frame in order to be effective, there is a swivel action between the thoracic pressure pad and the adjusting arm in the back and the short supporting bar in front This permits a moderate degree of motion of the thoracic pressure pad around its longitudinal axis and allows the pad to remain in contact with the moving thorax The pelvic frame is closed in front with a single strap, if the level of the apex of the curvature is low If it is higher, an additional strap connects the ventral end of the thoracic pressure pad with the link unit of the pelvic frame on the opposite side As a rule it is not necessary or desirable to add a belt like abdominal part to this type of brace This may be necessary only in the rare cases where an active correcting spinal brace is indicated in the presence of a weak abdominal wall or in cases of obesity Elastic material should then be used

A word must be said about the use of shoulder straps These are easily attached to a slightly padded right angle bar which is riveted to the thoracic pressure pad in the back The straps then run over both shoulders and back to the bar through the axillae Opinions differ as to the advisability of such shoulder straps They have two distinct advantages

1 If the patient leans forward in the sitting position, as for school or office work, the thorax moves away from the brace, or the brace "runs away" from the body, thereby rendering the force entirely ineffective The shoulder straps will hold the brace to the body. This is especially true if the thoracic pressure pad must act at a higher level The shoulder straps are not necessary if the apex of the curvature is situated in the lumbodorsal region

2 In a defective posture with a tendency toward dorsal kyphosis in addition to scoliosis, the shoulder straps act as a "reminder"

Shoulder straps are condemned by some authorities for obstructing the aim of the active correcting spinal brace Their action on the shoulder girdle and consequently on the thorax is said to oppose the desired action of the active correcting brace on the spine as it interferes with the straightening and subsequent elongation of the spinal column I feel, however, that a shoulder strap introduces only moderate, more or less elastic, auxiliary forces They are permissible in many cases and often valuable when the thoracic pressure pad is at a high level and in cases with a tendency toward dorsal kyphosis

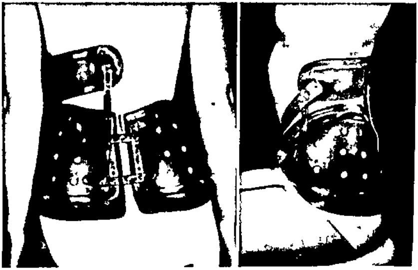


FIG 30 Active correcting spinal brace on patient with left lumbar scoliosis

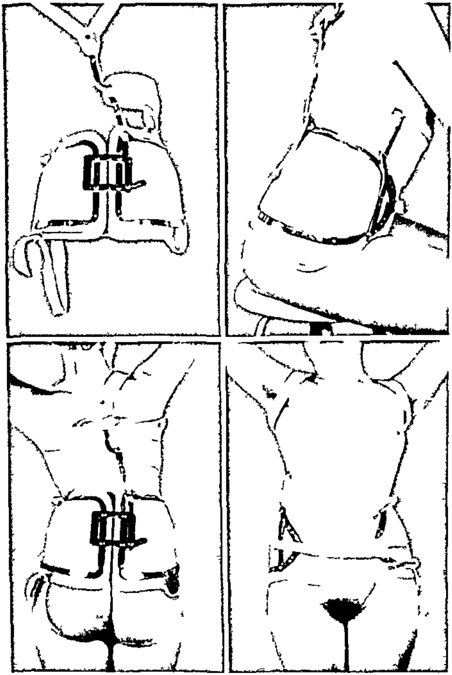


Fig 31 Active correcting spinal brace with perineal strap on the left, and trochanter pressure pad on the right side In addition to a leather strap connecting the pelvic frame in front a larger abdominal support made of two wide elastics is used Shoulder straps are required to insure correction with the patient sitting.

BUILDING THE PASSIVE SUPPORTING SPINAL BRACE

By ALFONS R GLAUBITZ

Preparation of the Plaster of Paris Model

The plaster of Paris model is placed on a turntable which allows easy access to the model throughout the entire construction procedure without losing the correct alignment of the model with reference to the plumb line and the horizontal or level plane The top of the table must be level When the model is properly placed on this table, symmetrical corresponding parts, such as the iliac crests and the anterior superior spines, will be in the same horizontal plane The plumb line is determined and drawn on the model which has already been landmarked and corrected In designing the brace, first the double frame hinge is drawn on the model The joint of the hinge is placed in the plumb line over the middle of the sacrum Its height is determined by the fact that it has to be one inch below the fifth lumbar vertebra and one inch above the horizontal plane of the trochanter

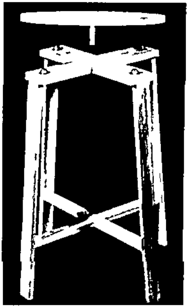


FIG 32 Swivel table recommended for the building of spinal braces

Next, the pelvic frame is drawn with the vertical back bars parallel to the vertical part of the double frame hinge, one inch lateral to the plumb line The vertical bars extend down to the trochanteric plane and up to a point one inch below the height of the iliac crest

We then turn to the front of the model by rotating the turntable The left and right anterior connecting bars, which join both ends of the pelvic frame, are drawn symmetrically just below and medial to the anterior superior spines These connecting bars have to be long enough to hold two screws and give one inch extension

To complete the pelvic frame, two lines are drawn one from the posterior vertical section of the pelvic frame over the iliac crest to the upper section of the front connecting bar, the other from the lower posterior section of the pelvic frame, going horizontally over the trochanter and then curving upward and forward to the lower section of the front connecting bar

Next, the thoracic frame has to be designed Starting with the posterior link unit, with its joint in the plumb line at a level determined by the site of the spinal lesion, but always considerably below the level of the axilla, the infraclavicular pressure pads are marked off on the model below the landmarks which determine the position of the clavicles The thoracic frame is traced downward from the infraclavicular pressure pad, curving laterally, and leaving sufficient space for the pectoralis major muscle On the lateral aspect of the model, the thoracic frame is traced from in front upward in a downward direction to the back at a level of one to one and one-half inches below the axilla The thoracic frame reaches the lowest point at the site of the scapula and rises slightly to join the posterior link unit The anterior and posterior lateral rigid uprights on either side are constructed as extension bars connecting the pelvic and the thoracic frames in the frontal

planes just anterior and posterior to the axilla While the posterior upright is drawn in a straight line perpendicular to the horizontal top bar of the pelvic frame the anterior upright follows a course vertically down on the thoracic wall and then curves slightly to the back until it reaches the pelvic frame just above the proximal arm of the anterior extension bars The two posterior steel springs which are fastened to the pelvic frame and constructed to support the corset lacer from one inch above the thoracic frame downward are traced as an extension to the vertical section of the pelvic frame

The breastplate or yoke connecting the infraclavicular pressure pads and the two angle irons connecting the pelvic frame with the rest of the steel construction are not designed until after the second fitting

Slots about 1 inch in length are filed into the horizontal parts of the hinge for expansion of the pelvic frame

2 A paper pattern is cut to the tracing on the plaster model for the two halves of the pelvic frame The two halves are forged to the paper pattern from surgical or stainless steel to a thickness and width of about $\frac{1}{8}$ inch x $\frac{5}{8}$ inch Outside surfaces are beveled except for the posterior vertical bars and the distal ends of the frame to which the connecting bars are to be attached

3 The anterior connecting bars of the pelvic frame are cut from $\frac{1}{8}$ inch x $\frac{1}{2}$ inch sheet steel or stainless steel At the apex of the triangular shaped bar a stud is riveted to hold the front strap

4 A paper pattern is made from the drawing on the plaster model for the thoracic

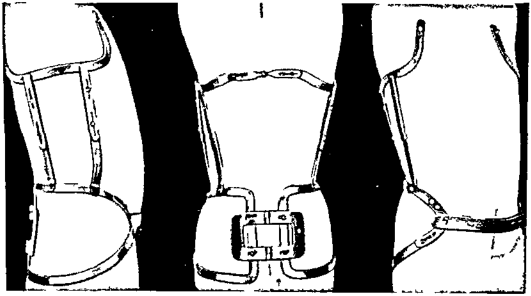


Fig 33 Steel skeleton of a passive supporting spinal brace on the plaster model ready for the second fitting The two posterior flexible uprights and the small angle irons are still missing

Specifications and Preparation of Parts

1 The double frame hinge is made of two U" shaped components and is forged to the size of the drawing on the plaster model $\frac{1}{8}$ inch thick and $\frac{5}{8}$ inch wide The joints are milled and squared so that they work freely

frame which is forged in two halves from surgical or stainless steel Posteriorly the thoracic frame is connected by the link unit which is made from the same material Anteriorly the thoracic frame carries the clavicular pressure pads These are cut from 16

gauge stainless steel Studs to carry the yoke or breastplate are riveted to the clavicular pads

5 The four lateral bars connecting the pelvic with the thoracic frame are built as extension bars These are cut from $^3/_8$ inch x $^9/_{16}$ inch surgical or stainless steel The upper extensions to which slots are filed for $^8/_{32}$ inch screws are riveted to the thoracic frame The lower extension bars are fastened to the pelvic frame with only one $^8/_{32}$ inch screw To steady the thoracic frame on the pelvic band angle irons are cut from the same material These angle irons are later fastened to the pelvic frame and extension bars when the proper relationship between the pelvic and thoracic frame has been ascertained The posterior steel springs rise from the vertical section of the pelvic frame and are cut from 050 x 1 inch tempered spring steel The placement of angle irons may vary from time to time

6 The anterior breastplate or yoke is cut from 16 gauge sheet metal or stainless steel to about one half inch in width As the proper location for the infraclavicular pads cannot be known until the first fitting of the brace the filing of slots for the studs on the infraclavicular pads is postponed

7 The corset parts of the brace are made of heavy coutil or preferably pekinstripe material

Building the Brace

The pelvic frame is formed on lead following the tracing on the plaster model The iliac crest bar of the pelvic frame extends forward and downward to a point medial and below the anterior superior spine where it is overlapped by the anterior connecting bar The lower part of the pelvic frame passes above the trochanter horizontally upward and forward to the lower arm of the connecting bar Care should be taken that the lower bar of the pelvic frame does not interfere with the sitting position of the patient When the two halves of the pelvic frame are fitted correctly to the model the anterior connecting bars are attached to the pelvic frame with $^9/_{16}$ inch screws and posteriorly connected to the double frame hinge with $^8/_{32}$ inch screws The pelvic frame is then ready to be fitted to the patient

At the first fitting the pelvic frame is adjusted to the patient's body It must clear the iliac crests and the front units must have the correct relation to the anterior superior spines Necessary adjustments can be made by means of the slots of the anterior connecting bar as well as the slots of the double frame hinge After the pelvic frame has been fitted with the patient standing sitting walking and bending down it is returned to the shop It is frequently found that after the first fitting the shape of the pelvic frame has been changed and it may be difficult to replace it on the plaster model In this case the plaster model must be reshaped to fit the pelvic frame and not vice versa

The thoracic frame is formed on lead following the tracing on the plaster model Special attention must be given to the position of the infraclavicular pressure pads and to the section of the thoracic frame which has to be shaped convex to the lateral wall of the thorax below the axillae At this time it may be necessary to scoop out some plaster at the site of the infraclavicular pressure pads as well as below the axillae The two halves of the thoracic frame are then joined in the back by the link unit for which slots were provided using $^8/_{32}$ inch screws

The upper parts of the lateral vertical extension bars are riveted to the thoracic frame The lower sections of the extension bars are hammered to the shape of the plaster model and attached to the pelvic frame by one $^8/_{32}$ inch screw

A leather strap is prepared for the studs on the anterior connecting bars Another leather strap is prepared to be attached to the infraclavicular pads in place of the yoke which was prepared but left without slots

If the form and shape of the pelvic frame have not changed since the first fitting, it will fit the patient correctly The thoracic frame, with the infraclavicular pads in place, is adjusted to the patient's body, taking advantage of the lateral extension bars and the slots in the posterior link unit, and using the bending irons as little as possible When proper fitting of the entire steel frame is obtained, the relation of the thoracic and pelvic frame is definitely stabilized by the positioning of the angle irons which connect the posterior lateral rigid uprights with the pelvic frame Finally, the place of the slots is marked on the yoke

The fabric material for the corset lacer is now cut according to the measurements and patterns taken from the plaster model The center section or spinal pressure pad, supported by the flexible vertical back bars, extends in height from the pelvic frame to about one inch below the thoracic frame and in width to about an inch lateral to the flexible upright back bars The lateral or side sections are fitted with a leather strip by means of which they may be slipped over one of the anterior or posterior rigid uprights Two inch pressure must be allowed at each lacing The posterior corset lacer may be divided into an upper and lower section to enable it to conform more efficiently to a markedly deformed spine

The corset front is also held by leather strips to either the anterior or posterior lateral extension bars Should the front section of the corset and the posterior lacer have to be attached to the frame or posterior lateral extension bar, both sections are sewn on the same leather strip A strip of russet calf leather, with eyelets, is sewn to the section of the corset front on the side of the iliac crest and the anterior superior spine A lacer will hold the corset front in place and maintain the contour of the anterior section of the pelvic frame A good support for the abdominal muscles will then be provided

If no corset is desired, an abdominal pad with corset stays will take the place of the corset lacing reaching from the symphysis to about one inch above the umbilicus The proximal end of the abdominal pad is held by straps and buckles around the anterior extension bar Its distal section is reinforced with leather about one to one and a half inches in width, ending in a strap on either side to fit a buckle fastened to the lower section of the pelvic frame A narrower leather strap is sewn to the center section of the abdominal pad and its ends are connected to the studs on the anterior connecting bar of the pelvic frame

Finishing the Brace

All high carbon tool steel bars are nickel plated and the screws are replaced with new ones Wherever possible, finer set screws, such as $^{6}/_{10}$ inch and $^{5}/_{32}$ inch screws, should be used throughout

The pelvic and thoracic frames are covered with russet calf leather Light felt padding is placed on the thoracic frame at the axillae The leather is moistened in water and sewn to the frame with a single foot shoemaker machine The clavicular pads are padded on the inside with ½ inch felt and covered with chamois or medium weight horsehide The corset lacer and corset front are reinforced with corset stays To prevent the corset stays from protruding through the fabric, short leather strips are sewn over the ends of the corset stays and the fabric material is bound with tape

The yoke which had been cut to proper length and slotted is nickel plated and covered with russet calf leather The external covering of the yoke is cut long enough to cover the studs of the infraclavicular pads

After the brace is assembled, the double frame hinge is covered with leather At the ends, a 1 inch section of leather is sewed to the underside of the leather to form pockets into which the double frame hinge will slip in order to prevent wear and tear on clothing

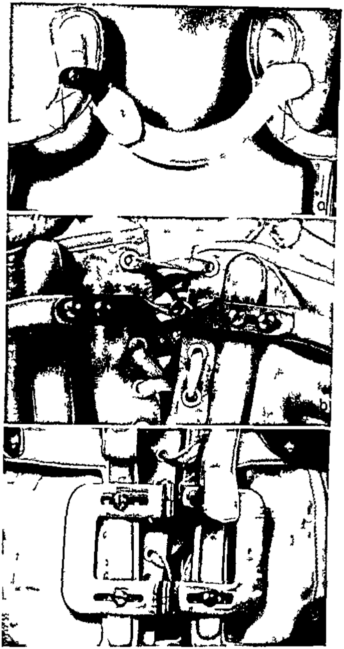


FIG 34 Passive supporting spinal brace (a) The breastplate or yoke and its attachment at the infraclavicular pressure pad (b) The posterior link unit connecting the two halves of the thoracic frame (c) The double frame hinge

BUILDING THE ACTIVE CORRECTING SPINAL BRACE

Preparation of the Plaster of Paris Model

The plaster of Paris model on which the molded leather sections for pelvis and dorsal pressure pads have been stretched is placed on the turntable and plumb lined according to the instructions given for the passive supporting spinal brace The tracing of the pelvic frame with the anterior connecting bars is exactly the same as for the supporting brace

The double frame hinge is drawn on the model with the joints in the plumb line The lower horizontal section of the hinge carries an extension for fixation of the posterior lever arm This extension is unilateral on the side of the curvature and about one and one half inches long

The thoracic pressure pad is drawn on the model at a level and in the direction determined by x ray examination Its size varies with the requirements of the individual case The force exerted by this pad should act on the thoracic cage in the direction of the course of the rib which leads to the vertebra at the apex of the curvature The long axis of the pad is not horizontal being lower in front

Next the posterior lever arm to which the thoracic pressure pad will be attached is traced on the model It will pivot on a short extension of the pelvic frame which was obtained when it was forged The posterior lever arm is constructed as an extension bar permitting adjustments of the level of the thoracic pressure pad Similarly the anterior supporting bar of the pressure pad is drawn on the model

If shoulder straps are to be used supports for these are traced on the plaster model and consist of a right angle metal bar with the small arm horizontal and riveted to the thoracic pressure pad and the long arm constructed vertically upward ending in the plumb line at the proper level

Specifications and Preparation of Parts

1 The double frame hinge is forged to the size of the drawing on the plaster model from high carbon tool steel or stainless steel to $\frac{1}{8}$ inch by $\frac{9}{16}$ inch On the side of the curvature an extension of about $1\frac{1}{4}$ inches long is welded or brazed to the double frame hinge The joints of the hinge are squared and must work freely Slots for $\frac{8}{32}$ inch screws are filed into the horizontal sections of the bar Holes for the $\frac{8}{32}$ inch screws are drilled $\frac{1}{4}$ inch apart for the posterior lever arm

2 The pelvic frame is forged from high carbon tool steel or stainless steel to a thickness of about $\frac{1}{8}$ inch by $\frac{3}{8}$ inch according to the size of the brace to be constructed The outside surfaces with the exception of the vertical section of the pelvic frame are beveled On the side of the curvature of the spine the vertical section is elongated and forged wider at the upper angle to hold the main pivot for the thoracic lever arm

3 The front connecting bars are cut from the same material as the pelvic frame Slots for adjustments and studs for the front straps are added to the front connecting bars

4 The material for the thoracic pressure pad is cut from 16 gauge stainless steel and is not to be more than $1\frac{1}{2}$ inches wide A reinforcement bar of about $\frac{1}{8}$ inch by $\frac{1}{2}$ inch is riveted to the entire length of the pad Its ends extend to contact the posterior lever arm and the front supporting arm which will carry a semi ball and socket joint

5 The posterior lever arm is made as an extension bar with its mid section forged wider at the side of the pivot on the pelvic frame and at the lower end where it will be attached to the extension of the double frame hinge The upper extension bar of the lever arm carries a semi ball and socket joint The anterior supporting bar is also made as an extension bar with its upper portion fitted with a semi ball and socket joint This arrangement will permit the thoracic pressure pad to pivot slightly on the bars and exert a full surface pressure on the thorax

6 If shoulder straps are to be used a bar is made for their support It is bent at right angles with one arm riveted to the thoracic pressure pad At the end of the longer arm a small metal plate with a stud or buckle is added to which the shoulder straps are fastened

7 Two and one half ounce molding leather is used for the pelvic section of the brace and the thoracic pressure pad and six ounce aniline strap leather for the front and shoulder straps

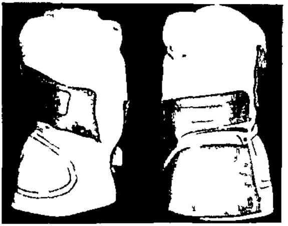


FIG 35 Molding leather is stretched over the model for an active correcting spinal brace with a left lumbar and a right dorsal pressure pad The leather sections are molded over the sheet metal pressure pads The steel skeleton is not yet applied A strap holds the pelvic section of the leather close to the iliac crest

Building the Brace

The pelvic frame is hammered on lead to fit over the molded leather section on the model The procedure described for the passive supporting spinal brace is followed

The fitting of the pelvic section does not differ from the description for the passive supporting spinal brace

Correct placement of the thoracic pressure pad is checked by x ray of the spine with the patient wearing the brace standing upright When the thoracic pressure pad is properly placed and connected with the pelvic frame by means of extensions of the posterior lever and anterior supporting arm it is important to study the effect of the thoracic pressure pad on the position of the pelvic frame

If the spine is not freely movable and can not readily yield to the corrective force or if too much correction is attempted there will be a tendency for the pelvic frame to rotate and lose its proper position on the body This must be counteracted not by altering the well fitted pelvic frame but by diminishing the corrective force of the thoracic pressure pad and if necessary by introducing additional forces to hold the pelvic frame in place Such forces are a trochanteric pressure pad attached to the pelvic frame on the same side as the thoracic pressure pad and a perineal strap on the opposite side If x ray control has shown the desired action of the correcting force and if the fitting of the pelvic frame has been assured the brace is returned to the shop for the leather work

Finishing the Brace

The molding leather of the pelvic section is taken off the brace and its edges are smoothly finished and sandpapered The edges are then moistened and rubbed to a luster finish with a dry cloth A thin coat of white shellac is applied to the leather The rivet holes in the steel frame are countersunk and all screws are checked and replaced if they are worn The pelvic frame is polished nicked plated and riveted to the molded leather pelvic section The pelvic frame is then covered with a moistened russet calf leather which is either sewn on by hand or by a single foot shoemaker machine The lining which may consist of good chamois or medium weight horse hide is pasted into the pelvic section and sewn around the edges The small stainless steel plate prepared in the event that shoulder straps are needed is padded slightly and covered with light leather The brace is then assembled

THE CELLULOID OR FIBERGLASS SHELL

In the treatment of pathological conditions of the spine requiring support, correction, or both, the forces introduced by applying a spinal brace should not be limited to the time when the patient wears the major appliance but rather for twenty-four hours each day. In addition to the spinal brace, treatment must include an orthopedic appliance of celluloid or fiberglass to be used at night.

The technique for making a mold for such an appliance for the back was described in Chapter 1, pages 19 to 21. When the negative mold is dry, it is prepared for casting by building up lateral walls on the four sides. Plaster of Paris cream is then poured into the mold, which is discarded when the model is dry.

After the plaster of Paris model has dried and been sandpapered, it is ready for the celluloid or fiberglass work provided that the final appliance is to be used for support and immobilization with the patient in a recumbent position. This would apply to cases of tuberculosis or osteomyelitis of the spine, certain types of compression fractures of the vertebrae, and for postoperative care after surgery for fusion of the spine. If, however, this orthopedic appliance is intended to maintain correction of a deformity, particularly a scoliosis, this plaster of Paris model requires much more correction than the model for a spinal brace.

Corrective forces are introduced by removing plaster of Paris with a draw knife from prominent parts, especially from the posterolateral aspect of the thorax on the convex side of the spinal curve, and at two places on the opposite side—usually high up toward the axilla and low down at the pelvis between the iliac crest and the trochanter. This introduces the three point system in the frontal plane. When the orthopedic surgeon has approved the correction of the model, its surface is again smoothed out by means of thin plaster of Paris cream and sandpaper.

Wherever it is available, fiberglass should be used in preference to celluloid for this appliance as it is lighter in weight, less bulky, and can be easily washed and disinfected. The technique for its use will be described in Chapter 5, pages 164-6.

Materials for the Celluloid Shell

- 3 pounds white celluloid scrap
- 2 gallons commercial acetone
- 2 yards burlap or glass cloth
- ¼ x ⅛ inch steel reinforcement
- 1 yard linen for covering the felt
- 1 sq. yard white orthopedic felt

On the front (flat side) of the corrected model, nails are placed about two inches apart in order to fasten the cord which will hold in place the component layers of the celluloid shell. After the plaster model is covered with stockinette, one-half inch white orthopedic felt is stretched over the entire model, reaching from the pelvic region up to and well over the shoulder and covering both lateral sides well down to the working bench. The felt pad is held to the model by criss-crossing a cord back and forth over the nails until the felt pad is securely fastened to the model. Wax paper is then placed over the felt pad to act as a parting agent between the felt and the shell. A sheet of burlap or glass cloth is placed over the entire model and firmly attached by frequent turns of cord. Extra heavy celluloid cream is pressed into this layer. This procedure is repeated for the second layer of burlap or glass cloth. Two bars of ½ inch x ⅛ inch steel are then fitted to the model, beginning at the pelvic region and extending up and over the shoulders. Two bars of the same size are placed on the lateral sides of the model. One horizontal bar is then placed below the iliac crest and another over the shoulder ending in the axillar region. If a head piece is needed, a center bar from the pelvic region to the center of the head piece is added. Loose hemp cord, soaked in celluloid cream, is pressed along the edges of the steel skeleton to insure perfect imbedding of the bars. The third layer of burlap or glass cloth

is then placed over the model and held in place by the cords The entire surface of the shell is then painted with several coats of celluloid until a smooth finish is obtained

When the celluloid shell is completely dry it is removed from the model for fitting If the model has been well prepared the patient will be able to lie comfortably in the shell and receive the necessary support and correction The shell is cut to the proper size giving freedom to arms and neck (if made without a head piece)

The felt pad which had been kept separate by means of the wax paper is covered with white linen and tufted like a quilt The inner side of the shell is then painted with celluloid or lined with horsehide and the edges are finished smoothly Eyelets in each corner of the shell and lacers sewn to the felt pad will hold the pad in place Finally

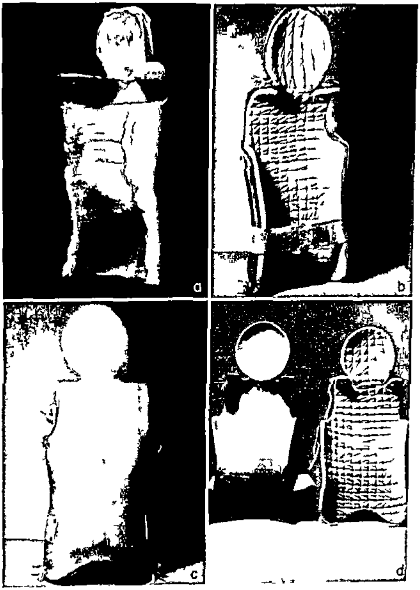


Fig 36 (a) Plaster of Paris mold for a celluloid night bed (b) Celluloid night bed with head piece inside view (c) Outside view (d) The lining is removable

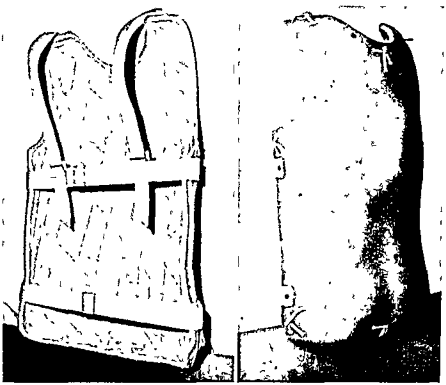


FIG. 37. Fiberglass bed without head piece.

straps may be applied to the pelvic and chest regions on the shell in order to hold the patient in the shell while he sleeps if this is required.

In this chapter, we have aimed primarily to discuss construction principles for the most efficient spinal braces and to describe their manufacture. Limiting ourselves to appliances which we have found most successful in the treatment of various spine conditions, we have given detailed accounts of the passive supporting and the active correcting spinal braces, as well as the celluloid and fiberglass shells for supplementary use These are suitable for almost every indication and, at the same time, represent good examples of the practical application of construction principles.

There are, however, many other solutions to the problems discussed in this chapter. While it is not the purpose of this manual to describe or even enumerate a great number of individual brace constructions, a few appliances deserve to be mentioned, especially those which differ in principle, materials, or techniques from our standard models.

THE CELLULOID CORSET

This construction is frequently used to support and maintain the position of the spine in place of a plaster of Paris cast. It is very light, fairly durable, and cheaper than many other braces. Its indication, however, is limited particularly by the fact that it introduces only moderate forces and does not permit later adjustments. In prescribing such a corset, one must remember that the skin of a number of patients is sensitive to celluloid.

The plaster of Paris model should be carefully prepared for a celluloid corset in order to obtain the desired action of the brace and to avoid pressure on bony prominences. This is all the more important as only minor alterations can be made on the finished product.

The Manufacture of a Celluloid Corset

The plaster of Paris model is covered with wax paper in order to prevent the celluloid

from adhering to the model A first layer of gauze or stockinette is then applied and the celluloid acetone solution of a syrup like consistency painted on with a heavy brush Four or five coats of celluloid will be used for each layer of gauze or stockinette and depending on the size of the brace four or five layers of gauze or stockinette will be necessary After the final coat is applied to the last layer the corset should be kept on the model for at least twenty four hours It is then cut in front along the midline of the body and taken off the model Finally, the wax paper is removed and the inside of the corset is treated with sandpaper

If the fitting does not take place on the same day the corset is replaced on the model If this is neglected the edges will turn inward and the corset will lose its shape After the corset is fitted and trimmed, the edges are sandpapered and finished by rubbing with a piece of cloth dipped in celluloid until a smooth finish is obtained If a smooth surface cannot be obtained by sandpapering the inside a thin coat of celluloid may be applied The cut edges in front are fitted with long barreled hooks for the lacing

As a rule the light celluloid corset requires no steel reinforcements If, however metal parts must be added in an individual case they should be riveted to the outside of the corset They should not be placed between the layers of gauze or stockinette

At present fiberglass is frequently preferred to celluloid for such a corset The fiberglass appliance is thinner and lighter and also more rigid than the celluloid corset This rigidity however may be a disadvantage for some patients who do better with the more flexible celluloid

THE LEATHER CORK CORSET

Another brace construction of distinct merit the leather cork corset was introduced by G Hohmann* The purpose of this appliance is to support the spine and the thorax in cases of the most severe deformities with marked shortening of the cranio caudal diameter of the thorax caused by gibbus kyphosis scoliosis or a combined deformity The brace aims to supply the kind of support which one could give to the thorax by bracing it from below with both hands The basic form of such a support is similar to the shape of a flower pot and it has therefore been termed Flower Pot Corset by Schrader

*Professor Dr Georg Hohmann Director Emeritus Orthopedic Hospital of the University of Munich Germany

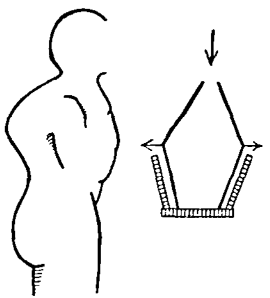


Fig 38 Fixed dorsal kyphosis of highest degree supported by a flower pot corset After Schrader (from G Hohmann *Orthopädische Apparate und Bandagen* Stuttgart 1938 courtesy Ferdinand Enke)

The Manufacture of the Leather Cork Corset

A plaster of Paris cast is made under moderate suspension of the body The iliac crests and the lateral wall of the thorax especially the distal ends of the ribs are carefully molded Molding leather is molded and nailed to the model in two parts one for each half of the thorax The technique is similar to the one described for the leather work in the

manufacture of the active correcting brace (page 56, point 7) The leather will conform to every detail of the model, its surface will therefore be quite irregular. To reinforce the molding leather and to produce a more equal external surface, a paste consisting of cork-meal and celluloid is applied until the desired contour is obtained. Light steel reinforcements, arranged in the vertical axis of the corset, may be embedded in the cork-meal celluloid paste. When the leather-cork part of the corset is completely dry, it is taken from the model and fitted. If the fitting is satisfactory, the two halves are covered with coutil and united by means of a lacing in the front and back, similar to the old-fashioned woman's corset A strong, one-inch strap of webbing with buckle is applied just above the iliac crest in order to increase the concentric pressure of the two halves of the molded corset and to effect a moderate degree of extension of the spine.

Emphasizing that it is light in weight and provides a firm seat and good support, Hohmann has reported consistently good results in selected cases throughout the years with this type of leather-cork-corset. Our experience has been equally encouraging.

For treatment of scolioses and kyphoses, a number of spinal braces have been designed in recent years, according to the construction principles based upon the action of a three-point system They introduce a strong correcting force acting on the apex of the main curvature by means of a lever which pivots on a pelvic frame. The action of such a brace depends, first of all, on the pelvic frame which has to be carefully fitted and of sufficient strength to retain its position when the correcting force on the spine is introduced by adjusting the lever. The appearance of

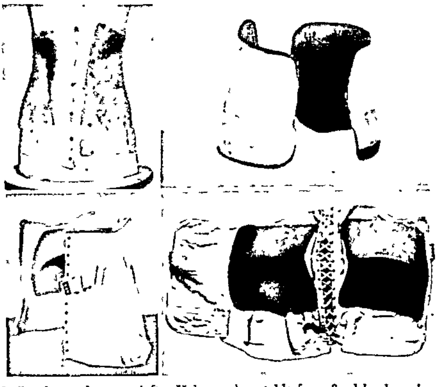


FIG. 39 Leather-cork-corset (after Hohmann), suitable for a fixed kyphoscoliosis where support is required but no correction is attempted.

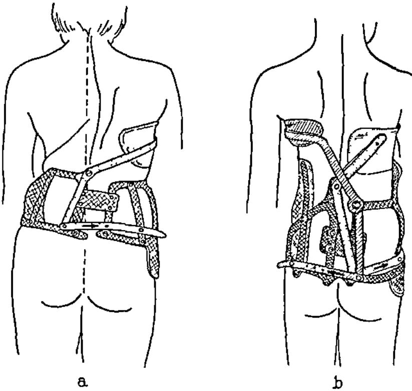


Fig 40 Hohmann's single lever (*a*) and double lever (*b*) corset for correction of C and S shaped scolioses (Redrawn from G Hohmann *Orthopadische Apparate und Bandagen* Stuttgart 1938 courtesy Ferdinand Enke)

some of these braces is similar to our active correcting spinal brace They must be designated as passive braces however even if they are not of the supporting type Hohmann has designed such a brace with one or two levers (Fig 40)

THE JEWETT HYPEREXTENSION BACK BRACE

The Jewett hyperextension back brace and its modifications present a classic example of the three point system of forces Rightly, it has found its definite place in the treatment of pathology of the spinal column While this orthopedic appliance is available commercially, we prefer to make it to the patient's individual measurements and tracings A distinct advantage of this appliance is that it can be completed within one day It is frequently preferred to the passive supporting spinal brace for acute conditions of the spine

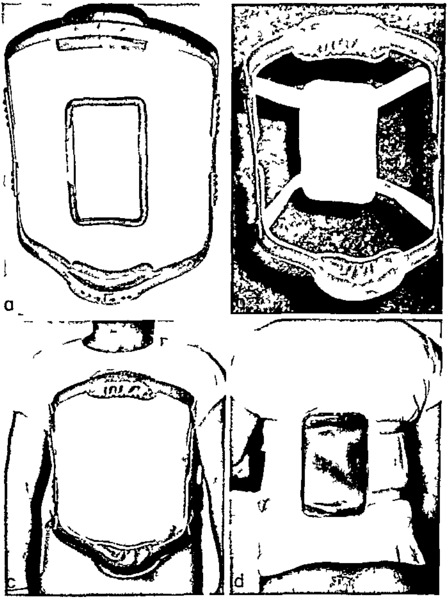


FIG 41 The Jewett Hyperextension Back Brace (a) metal skeleton (b) brace completed (c and d) brace on patient Three point system of forces is clearly demonstrated

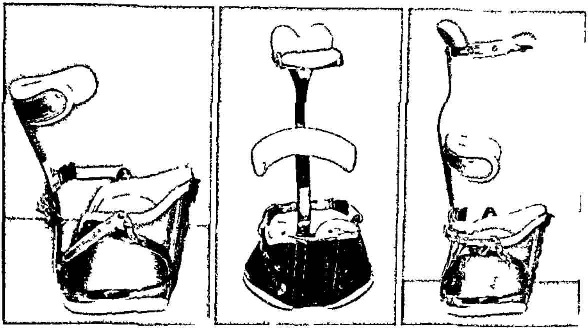


FIG 42 The Anti Gravity Spinal Brace (courtesy Alfons R Glaubitz)

FIG 43 The Anti Gravity Spinal Brace on a patient (courtesy Alfons R Glaubitz)

THE ANTI-GRAVITY SPINAL BRACE
BY ALFONS R GLAUBITZ

The anti gravity spinal brace for the treatment of juvenile kyphosis, exaggerated lordosis, congenital absence of abdominal musculature, frequently associated with megacolon (Hirschsprung's disease), and paralytic (acquired) abdominal wall, has been used on relatively few patients Its results, however, justify its inclusion in this manual Without the extension head piece, its use for postural lordosis is well established

The principle underlying its corrective forces is based on the three-point pressure system The fulcrum of the force is located at the sacrum, with the most proximal pressure point at the apex of the kyphosis Corrective forces to tilt the pelvis and flatten the lumbodorsal region are supplied by leather straps leading from the iliac crest to the posterior bar

For its construction, we use the same molded leather pelvic frame described earlier in this chapter for the active correcting spinal brace To this frame, we add a posterior bar consisting of 1 inch x $^{3}/_{16}$ inch, 6061-T4 aluminum and a horizontal steel crossbar about 4 inches in length To the distal and proximal ends, steel hinges are added to fasten to the pelvic frame and kyphosis pad On the iliac crest, an extension to the height of 1 inch x 1½ inches is added to hold the leather strap which leads to the steel crossbar holding the buckle The kyphosis pad is rather heavily padded to provide greater comfort to the patient

To apply the brace, the pelvic section is fastened securely to the patient The patient then flexes his trunk at the hips until the lumbar lordosis is flattened While the patient is still in this position, the medial and lateral leather straps are fastened to the buckle on the posterior bars If the brace is equipped with a head holder, care must be taken to provide sufficient head elevation and, at the same time, enable the patient to elevate his head slightly above the head piece

THE AMERICAN MILWAUKEE BRACE

BY ALFONS R GLAUBITZ

Since the original introduction of the first American Milwaukee brace several changes have been made to streamline this appliance which has its value in preoperative and post operative treatment of scoliosis

In our construction of this appliance, we use a rigid molded leather pelvic section, similar to that designed for the active correcting spinal brace We replace the leather strap and buckle with a steel plate on the posterior opening of the Milwaukee brace so that we do not have the double frame hinge used for the active correcting brace Good results have also been obtained by replacing the spinal pressure pad with derotating opposing leather pull straps

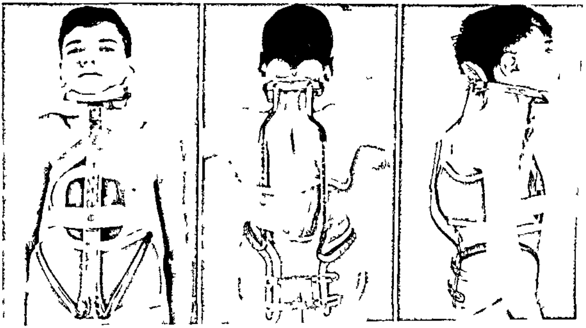


FIG 44 The American Milwaukee Brace

Treatment with the Milwaukee brace depends upon the correct lateral pressure on the spinal column from within the brace While head traction must be constant, over enthusiasm should be avoided The head traction must be held at a level enabling the patient to elevate his head slightly above the head piece of the brace During the period of treatment there must be frequent check ups by the orthopedic surgeon and the brace maker

SUPPORT FOR THE CERVICAL SPINE

A word must be added about the difficult problem presented by diseases of the cervical spine that require support, fixation or unweighting The necessity of introducing a strong force which acts on the head like a Glisson sling is always unpleasant for the patient especially in the male adult where the growing beard causes an irritation at the chin part of the brace

A support for the cervical spine and the head may be part of a supporting spinal brace In this case, it is generally built upon the infraclavicular thoracic pressure pads In some instances, such an appliance is indicated for the treatment of a defective posture of the neck and the head, where no spinal brace is required. The foundation for the supporting or correcting force is then supplied by a yoke which rests on the shoulders The entire ap

pliance is made to a plaster of Paris model, using molding leather and high carbon tool steel, or fiberglass To obtain the maximum comfort for the patient who has to wear such an appliance, the construction must be carefully adapted to the needs of the individual case The following figures show two examples of the many possible modifications

Fig 45 Leather metal appliances for the cervical spine The posterior uprights are made as extension bars The yoke is well padded over the shoulders with foam rubber

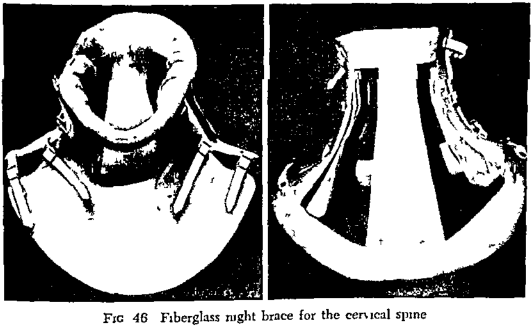


Fig 46 Fiberglass night brace for the cervical spine

Chapter 3

LOWER-BACK BRACES AND SUPPORTS

Abdominal supports and sacroiliac belts, often purchased without any medical supervision, are the orthopedic appliances second *only to arch supports that are most commonly* demanded by the public The reason for their popularity is the large number of conditions coming under the collective term "lower back pain," a vague expression that may mean *much, little or nothing*

In contrast to the first edition of this text we are eliminating all references to the diagnostic aspects of lower back pain which have led to prescriptions for the appliances to be *discussed in this chapter This point of difference* from the original volume is maintained throughout this manual, as we are concerned here only with material that is strictly related to the principles and practice of brace construction

Limiting our discussion to the causes of lower back pain which belong to the field of orthopedic surgery, the following three groups may be distinguished in order of frequency

1 Lower back pain of postural origin This means pain caused by conditions related to the statics and dynamics of the "upright posture"

2 Lower-back pain caused by disease of the bones, muscles and ligaments of this region

3 Pain which is referred to the lower back from higher sections of the spine This requires a spinal brace, as indicated in the previous chapter

The first group is by far the largest, representing the majority of conditions for which an orthopedic appliance of the lower back type is indicated

One important exception, however deserves detailed discussion Man's erect carriage, gradually developed in the course of evolution, has introduced *certain static and* dynamic factors which are of prime importance in orthopedic mechanics and which are therefore frequently touched upon in this book The principal change in establishing *the upright position* fell upon the pelvis, which has had to adapt itself to fulfilling the three fold task of weight bearing, weight transmission, and movement

By reason of their anatomical structure and *their conjoint action, the lower extremities,* the pelvis, and the lower spine represent *one unit,* a kinetic chain of links Any alteration in shape position and function of one of the links affects the entire chain This phenomenon is readily understood when observing the static and dynamic structure of both legs and of the pelvis Von Baeyer has coined the term "geschlossene Gliederkette," which means a closed chain of links If a person stands on both feet, such a closed chain is formed for example by Ground–left foot–left lower leg –left thigh–pelvis–right thigh–and back to the ground through the corresponding links on the right side The ground represents the final link in this closed chain The motion of *the sole of the foot on the ground occurs in* what may be considered as an additional joint and may, therefore, be termed "Aussengelenk," that is, an extrinsic joint If in this closed chain one knee joint, for example, is *flexed from full extension to 155° flexion, the* relative position of the other links in the chain immediately changes Flexion of the left knee joint causes dorsiflexion of the left ankle joint,

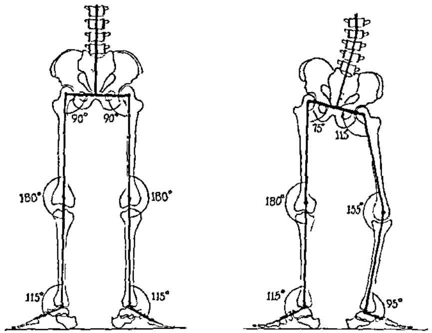


FIG 47 The principle of a "closed chain" (von Baeyer) Flexion of the left knee from 180° to 155° changes the angles at the left ankle joint and both hip joints as well as the position of the pelvis and the spine

abduction of the left hip joint and downward tilting of the left side of the pelvis Likewise a valgus position of the heel abduction of the forefoot and external rotation of the entire leg influence the position of the pelvis particularly its inclination and subsequently the degree of lumbar lordosis With the aid of this example we realize that the position of the foot has a direct influence on more proximal sections of the skeleton through the closed chain An understanding of the mechanism of the closed chain explains the fact that lower back pain is frequently caused by deformity or malalignment solely of the feet which leads to a secondary malposition of the pelvis We have found that abnormal conditions of the feet are responsible for approximately 50 per cent of the cases of lower back pain in group 1

In a certain percentage of cases the position of the feet is partly responsible for lower back pain as for instance in the large group of individuals suffering from mesenchymal insufficiency (Banderschlaffheit") who exhibit the syndrome of weak feet varicose veins relaxed pelvic floor atonic abdominal muscles and increased lumbar lordosis or some of its components

We may now proceed to discuss the construction principles of the orthopedic appliances for this region together with the mechanical effects which may be expected of them

The more important mechanical problems involved will be made easier to understand by an analysis of the pelvic architecture in the standing position According to H Braus in the upright standing position the promontory and the points of rotation of the legs in the hip joint lie in a vertical plane The pelvis in this plane has the form of a barrel or tunnel vault which bears the weight of the torso and distributes it over both thighs The vault is formed by both ilia and the sacrum Within it is a state of tensile stress The springy tension of the pelvic structure is responsible for the high degree of stability of the pelvis and the elasticity of the gait The tensile stress acts on the sacroiliac joints as well as on the symphysis The arrows (Fig 49) show the sig

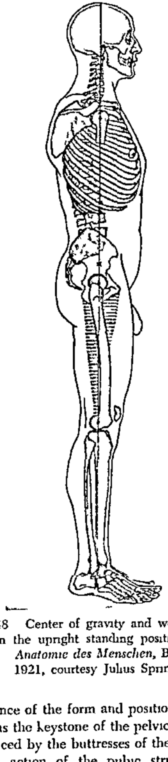


Fig 48 Center of gravity and weight distribution in the upright standing position (from H Braus *Anatomie des Menschen*, Band I, Berlin, 1921, courtesy Julius Springer)

nificance of the form and position of the sacrum as the keystone of the pelvic arch, which is braced by the buttresses of the ilia and the beam action of the pubic structures, and readily suggest the consequences of displacement or relaxation of its junctions

We learn from these considerations where and how a mechanical support for an imperiled or already weakened vault must act In architecture, a transverse, horizontal beam is fastened with *brackets to the buttress on* each side, thereby diminishing the tensile stress in the arch of the vault As intrinsic bracing of the human pelvis is impossible, an extrinsic construction must be chosen to fulfill the same mechanical purpose This is accomplished by bracing the pelvic ring with the aid of a circular strengthening hoop The hoop must be firm (non elastic) and, to act at the right site, it must lie between the iliac crest and the greater trochanter For practical purposes, the desired result is obtained most simply with a one inch strap of webbing which encircles the pelvis between the iliac crest and the trochanter and is fastened in front with a buckle The effect of this simple appliance is often quite startling It may therefore be used as a test before constructing a more complicated belt The principle of "hoop effect" must also be borne in mind in connection with the larger orthopedic appliances, to be discussed later

Having studied the mechanical basis in the *frontal plane of the upright body, we must* now discuss conditions in the sagittal plane Here, we shall have to consider pelvic inclination, lumbar lordosis position of the body's center of gravity, and tension of the abdominal wall Tension of the abdominal wall and position of the center of gravity are comparatively easy to influence directly Pelvic inclination and lumbar lordosis are much more difficult to influence, and sometimes this must be done indirectly as for example, by changing the height of the heels worn by the patient In this situation, relaxation of the contracted sacrospinal muscles plays a certain role

At this point we must mention auxiliary forces which, for the sake of their practical results, are more widely used than would be justified from a mechanical point of view We particularly refer to pressure pads in the lumbar and sacral region which appear to con-

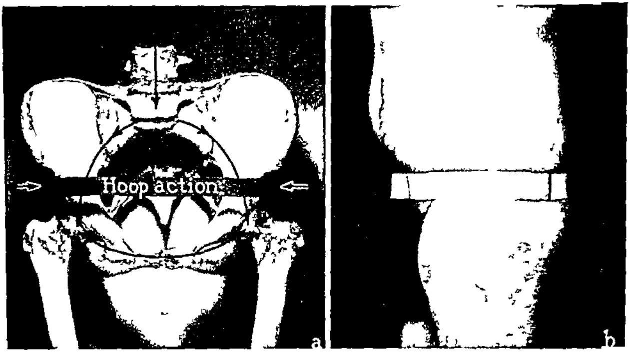


FIG 49 (a) Weight stress transmission through the pelvic arch (b) "Hoop-action" by means of a simple strap worn between iliac crest and trochanter

stitute the principle portion of commercial sacroiliac belts The advertised success of many of these belts is commonly attributed to the particular shape of these pressure pads There is no doubt that such pads often exert a subjectively pleasant supporting effect But essentially they serve merely as "reminders" they remind the wearer of the necessity of better posture through active muscular work being thus comparable to Spitzy s "Kugel einlage" (page 153 Fig 115) for the treatment of pes valgus in children On the other hand authorities such as Hohmann have stressed the importance of exact molding of the posterior surface of the sacrum in preventing upward displacement of the effective force and thus avoiding an increase in the lumbar lordosis Such a sacral support or pad may readily be incorporated in an apparatus which otherwise fulfills the two mechanical principles discussed in detail

If however a pathological inclination of the pelvis is to be combatted additional forces must be introduced for example at the lever arm of one or both thighs

Referring once again to the simplest appliance the strap for "hoop action" around the pelvis I shall describe our favorite *abdominal belt* and the *hinged lower back brace* To discuss or even list the countless partly effective and partly useless belts abdominal supports and braces which are prescribed and used for the relief of lower back pain would fill a volume in itself

Although individualized brace construction is imperative in the field of orthopedics a brace shop will work most efficiently if it employs several standard models which have stood the test of experience As in other chapters we shall limit ourselves to a description of those constructions which have proved most valuable

POLO BELT

The large number of patients with postural lower back disability of muscular origin requires more than just "hoop action around the pelvis" without having to resort to an abdominal belt or surgical corset A polo belt of

strong non elastic material, 5 inches wide, and fitted with leather straps and buckles, gives a firm support to the lower-back as well as to the abdominal wall This standard equipment of horsemen is frequently used by long distance drivers to avoid fatigue and the resultant muscle stiffness and pain This appliance deserves a trial before the elastic abdominal support is prescribed

ELASTIC ABDOMINAL SUPPORT

The elastic abdominal support, introduced in 1936 by William J Kerr and John B Lagen, fulfills all the postulates of such an appliance so completely that I regard this belt as the one of choice, although its manufacture and fitting are not easy The belt is constructed with the physiological function of the abdominal wall in mind and is designed to supplement and aid rather than to replace the ventral muscles Specifications, according to the authors, are as follows

The appliance is made of coutil, pekinstripe cloth and elastic goring, and is fastened on by skate buckles and hooks The front and back sections are of double thickness, the outer layer consisting of high quality coutil and the inner of pekinstripe cloth The latter, which is soft and fine, prevents chafing of the skin Both sections are tailored or fashioned The back section, 8½ inches in height, has three double stays of whalebone, with a seam at each, which permits the support to be fashioned to fit the outline of the patient In extreme lordosis, the cloth section in the back may be extended up to the twelfth thoracic vertebra and have firm Alcoa aluminum 2024 T4 or steel stays incorporated in it These stays should touch the body at the upper and lower edges of the belt, thus bridging the lordosed spine They should not be bent to fit the curve of the spine

The left front section is fitted with hooks and the right with straps carrying the buckles The left front section extends across the abdomen as a flap about 6 inches long The width of each half of the cloth section across the front averages 2½ inches The total width of the non elastic front which varies with the tightness of the belt, is 5 to 7 inches The front flap slips under the right side of the belt as it is tightened

The elastic sections each consist of two pieces of firm elastic goring, 6 inches wide and about 7 inches long placed one above the other The two pieces overlap about 2 inches in the center, giving greater support to the front center The lower piece of goring, facing diagonally downward toward the front on either side, exerts an upward lift rather than a straight posterior pull

The uplift strap consists of elastic and non elastic material The front forked section is made of firm elastic webbing 1½ inches wide which extends to a buckle placed toward the top of the belt just back of the hip allowing tightening or loosening of the strap as desired The diagonal uplift straps exert a supporting rather than compressing pressure on the lower abdomen

The belt is fastened in front with six skate buckles and hooks, with the buckles slipped

FIG 50 The influence of an effective abdominal belt on posture

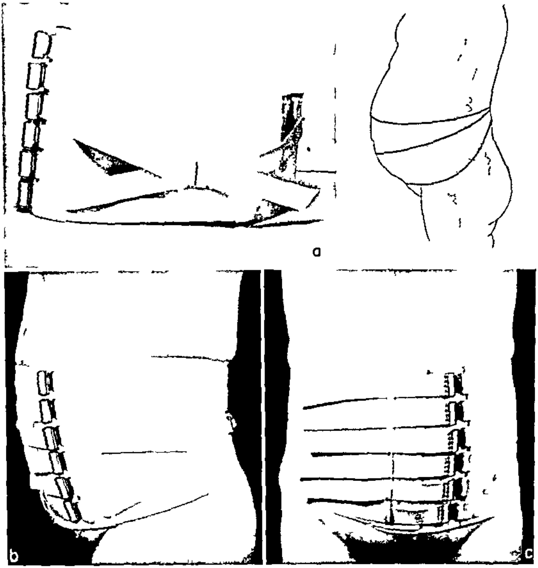


FIG 51 Elastic abdominal belt after William J Kerr and John B Lagen (a) Side view (b) belt on patient (c) front view The insert shows the lines of measurement

over the hooks with the strap loose Each may then be tightened individually The extra length of strap is held up by slots at the origin For a lighter belt eyelets and lacing may be used instead of buckles and straps with a zipper added if desired This is frequently preferred by female patients

In a number of cases we have combined an abdominal belt representing the main features of the Kerr and Lagen type with a fashionable brocade corset or an elastic girdle made to the patient s measurements Such an "inner belt corset" fulfills the medical indications without neglecting the requirements of fashion

Patients are instructed to put on the belt in a supine position over a thin garment before getting up in the morning and tighten it from below upward. This moves the abdominal fat and viscera upward and does not compress them in the lower abdomen.

The unusual features of the belt are the height and particularly the width of the elastic side sections achieved by making the front narrow and permitting the side section to extend farther forward on the abdomen where

elasticity is more beneficial than toward the back. Increased elasticity allows the belt to expand during inspiration. This aids rather than suppresses abdominal breathing and prevents limiting respiration to the thorax as is seen in obesity or where a firm non elastic belt is applied. Increased elasticity further aids in expiration overcoming the prolonged expiration in patients with depressed diaphragms caused by abdominal ptosis or emphysema.

THE HINGED LOWER BACK BRACE

The hinged lower back brace used everywhere under different names is the apparatus which we most frequently use for treating cases of lower back pain where the use of a lower back brace is indicated. The apparatus fulfills the postulates of bracing the pelvis by the "hoop effect" the required influence on the abdominal wall and the center of gravity. To a certain extent it thereby influences the pelvic inclination and the lumbar lordosis and in addition gives the patient the feeling of support to his lower back which he so frequently demands.

This construction has several distinct advantages. As a rule it is made to measure without a plaster of Paris cast. It is very light, scarcely visible under the clothing and adapts itself elastically to the body in all its movements, especially in the sitting position.

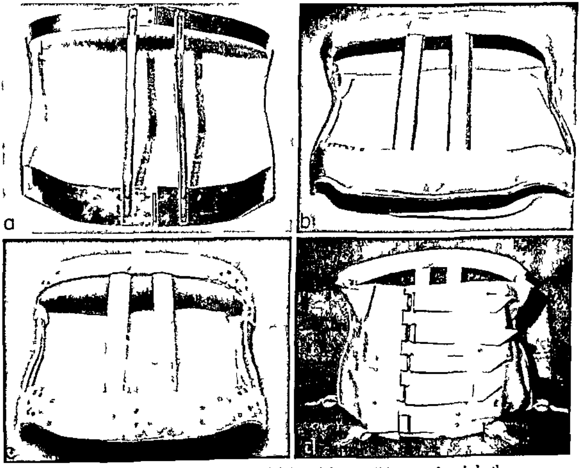


Fig 52 Hinged lower back brace (a) Metal frame (b) covered with leather (c) covered with brocade and (d) with semi elastic abdominal front

Finally, this hinged lower back brace may be combined with or worked into a girdle, such as one of the two way stretch elastic models which takes in the thighs and assures a good cosmetic appearance

Manufacture of the Hinged Lower-Back Brace

(BY ALFONS R GLAUBITZ)

The two pelvic components of the brace are made of stainless steel, aluminum or sheet steel These parts are 1⅜ inches wide at the sacrum and 1½ inches wide at their lateral portion The sections between these points slope toward the center to a width of 1¼ inch Both pelvic components are hinged at the sacrum with a continuous hinge If the components are made of stainless or sheet steel, gauge 18 to 20 will suffice If they are made of aluminum, 051 type 6061 T4 material should be used

The upper band is also made of two component parts hinged posteriorly with a continuous hinge The upper components are curved downward from the center to meet the slightly shorter lateral bars These parts are ⅝ inch wide and of the same thickness as the pelvic components Here, too, there is a choice of materials

For the posterior upright, we use ½ inch x 3/16 inch type 316 stainless steel bars These *uprights are riveted to the pelvic components,* 1½ inches lateral to the continuous hinge The lateral uprights should conform approximately to the contour of the patient

The corset front is made of coutil with an elastic insert of not less than 2½ inches To close the corset front, it is best to use eyelets and laces This will give greater support than webbing straps and buckles For the obese patient, it may be advisable to place additional lacers in the gluteal region

This brace permits many variations For the frame, we prefer 6061 T4 aluminum Pekinstripe material is suitable for the corset front The frame may be covered with leather, such as horsehide or russet calf The latter must be moistened before it is sewn onto the frame The entire appliance, including the corset front, may be finished in brocade For slim patients, the corset front with lacing in the midline is most effective In cases of obesity, we have had very satisfactory results with a corset front similar to the elastic abdominal belt It is important to cut the elastic inserts rather narrow

This lower back brace demands exacting measurements for its proper height The size and condition of the patient will influence the length of the lateral bars and corset front For a very obese patient, the lateral bars will have to be shorter than the corset front

To secure proper measurements, the length of the pelvic bands which form the foundation of the brace must be determined first Starting above and one inch anterior to the greater trochanter on one side, one must measure over the sacrum just above the coccyx to the other side until just above and one inch anteriorly to the greater trochanter The height for the posterior bars is measured to the level of the spinous process of the ninth dorsal vertebra In an obese patient, the posterior bars may be lowered down to the level of the spinous process of the twelfth dorsal vertebra

The upper metal band should never be longer than half the circumference of the body at the level selected for the height of the brace There will be a lesser curve in the upper band if for instance, the height of the brace is lowered to the level of the twelfth dorsal vertebra We find the height of the lateral bars by placing the tape measure just above the trochanter and over the iliac crest to a point where the two lower ribs can be enclosed

The corset front, beginning below the symphysis has usually the same length as the lateral side bars but must extend one inch above the umbilicus In a case of obesity or a pendulous abdomen, a higher corset front will be needed

After the measurements have been taken the metal frame is built according to specifications The six metal parts are cut to

proper length and width and the pelvic and upper bands are hammered into shape and hinged The posterior uprights hammered to the contour of the back must bridge the lumbar region because the uplift of the corset front will tend to decrease lumbar lordosis The posterior bars are then riveted to the pelvic band and the upper band is temporarily attached to the posterior bars As mentioned above the lateral bars must be shaped and riveted to the pelvic band

Next the corset front is cut and sewn together A leather strip which is sewn on each end of the corset front is slipped over the lateral bars which are temporarily attached to the upper band At this point the brace is ready for fitting

At the time of this fitting and usually only one is needed the frame is adjusted to the patient s body with the aid of bending irons If necessary the temporary rivets may be removed from the upper band on both sides so that the bars can be shaped more accurately to the patient s contour The height of the corset front is then confirmed and the brace is ready to be finished at the shop

The patient is instructed to apply the brace before getting up in the morning following the same procedure described for the abdominal belt

THE WILLIAMS LUMBOSACRAL FLEXION BACK BRACE

The Williams lumbosacral flexion back brace designed by Dr Paul C Williams is one of the most efficient lower back braces It has its definite indication for correction of increased lumbar lordosis pelvic forward tilt and spondylolisthesis It has been successfully used in certain cases of lumbosacral radiculitis whether the irritation of the spinal nerve roots is caused by spondylosis or disc herniation Although it is commercially available we prefer to make it to the patient s individual measurements

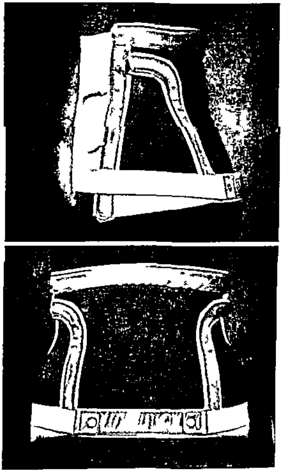


Fig 53 Williams Lumbosacral Flexion Back Brace

Chapter 4

APPLIANCES FOR THE LOWER EXTREMITIES

In constructing leg braces we are faced with two major problems created by the physiological tasks of the lower extremities stability for weight bearing and motility for locomotion Little can be accomplished by orthopedic appliances for the motility of the joints of the lower extremities It is usually not the purpose of a leg brace to attempt a greater range of movement of a partly ankylosed joint although this may at times be accomplished by a portative apparatus

Locomotion can be improved technically by the introduction of basic elements to compensate for lack of muscle tone and coordination as in tabes dorsalis or to substitute for the loss of active muscle power resulting from infantile paralysis The majority of leg braces however are intended to restore the function of the lower extremities as a weight bearing support for the body This may merely require bracing of a leg to provide the stability that is lacking because of a deficiency of the muscles tendons and ligaments which normally stabilize joints in the weight bearing phase or for a deficiency of the skeleton as in osteomalacia Pagets disease or pseudarthrosis Frequently unweighting of all or part of the extremity is necessary to eliminate stress or strain on a diseased bone or joint In these cases the unweighting may be part of the treatment or it may serve as a prophylactic measure in preventing deformities

In addition to the portative apparatus we shall consider the construction of night braces for the lower extremities that are worn to correct deformities or to maintain a correction already obtained by conservative or operative treatment

From these considerations we classify orthopedic appliances for the lower extremities as follows

1 Appliances which unweight or substitute for the entire leg or a part of it and which are almost equivalent to an artificial limb

2 Appliances which support or stabilize the leg or foot

3 Appliances which correct deformities or maintain correction

4 Appliances which substitute for the action of certain paralyzed muscles or for lack of muscle tone

Brace construction for the lower extremities is not possible without careful consideration of the anatomy and physiology of the parts to be treated The anatomy determines the proper site for the action of the forces which will be introduced by the brace Its study also reveals which part of the limb must not be subjected to pressure

The tuber ischii represents an almost ideal support for the weight of the body which it is made to carry in the sitting position It is therefore well equipped to transmit the body weight to the ground by means of an unweighting ischial seat brace if unweighting of the entire extremity is desired The thigh on the other hand offers no adequate foundation for weight transmission The large bulk of muscles and fat covering the femur is too soft and too movable Also the shape of the thigh changes according to the position of the leg It is different with the patient standing up sitting or lying down as well as when the knee joint or the hip joint is flexed or extended These facts must be borne in

mind when taking a plaster of Paris cast of the leg It may be difficult to build a well fitting Hessing-type leg brace for standing and walking on a model taken with the patient lying down While an encasing thigh brace will offer some auxiliary support as a result of friction between the brace and the surface of the thigh, a higher degree of weight transmission would require so much concentric pressure as to interfere seriously with circulation and nutrition of the muscles, and cause great discomfort to the patient It is possible, however to gain a valuable hold on the femur and prevent the undesirable upward and downward movements of a brace by considering the anatomical structure of the femoral condyles (though not in an unweighting ischial seat brace) and molding the cast, and accordingly the brace, close to the medial and lateral region of the lower third of the thigh just above the condyles In the popliteal region we must consider that on flexion of the knee, the tendons of the hamstrings, especially of the biceps femoris, are very prominent and extreme difficulty may be encountered if the thigh section of the brace reaches too far down toward the popliteal space In the lower leg another part of the skeleton similar to the tuber ischii seems to be prepared to stand pressure and carry weight This is the tuberosity of the tibia To a certain extent, it is possible to transfer weight bearing from the tuberosity of the tibia to the ground in cases where an unweighting of the ankle joint or the foot is desired Because the surface of the tuberosity of the tibia is almost vertical in the standing position, it is not always possible to solve the problem of weight transmission to this part of the skeleton Furthermore the efficiency of an unweighting brace limited to the lower leg can never be compared to an appliance designed to offer complete unweighting at the tuber ischii The form and shape of the lower leg are almost consistent in every position and therefore do not represent the difficulties encountered at the thigh Prominent parts of the skeleton which may not be exposed to pressure by a brace are the patella, the crest of the tibia, the head and neck of the fibula with the peroneal nerve, the malleoli at the ankle joint, the tuber of the os calcis with the insertion of the tendo Achillis and the distal part of the tendo Achillis proper, the dorsum of the foot in the mid-tarsal region, especially the joint between the first cuneiform and the first metatarsal and, finally, the tuberosity of the fifth metatarsal bone This is of vital importance in hemophilia

Trophic lesions of the skin, lack of subcutaneous fat, or atrophy of the musculature increase danger of pressure over prominent parts of the skeleton These conditions, as well as impairment of arterial or venous circulation, deserve special care in order to prevent undesirable complications

The usefulness of a leg brace depends, to a large extent, on the proper placement of its joints This represents the chief problem in brace construction for the lower extremities The correct site of the joint axes is well defined and described in textbooks on anatomy and physiology This knowledge is indispensable for proper brace construction A leg brace made with knee and ankle joints will fit only if the mechanical axes coincide with the natural axes If this is not the case, movements of the joints will cause friction between the brace and the leg, limitation of motion, or movement in abnormal directions To the patient, this means discomfort or pain and for a hemophiliac, there will be disability caused by joint hemorrhages This also produces stress on the brace, chiefly represented by shearing forces which lead to frequent breakage of the brace or, at the very least, loosening of its joints It is therefore necessary to determine the projection of the natural knee and ankle joint axes on the surface of the skin before starting brace construction regardless of whether a brace is made to a plaster of Paris model or built according to measurements and tracings of the limb to be treated In addition to correct alignment of the joints of the brace with regard to the anatomy of the leg we must also consider the

proper relation of the joints to each other This means that we must secure correct placement of the knee and the ankle joints along the weight bearing line of the extremity

Every portative apparatus for the lower extremities must be constructed with reference to the plumb line in order to guarantee correct weight bearing and a coordinated and congruent movement of the joints with reference to their axes In a normal leg in the upright position, the plumb line representing the center axis of gravity of the extremity runs from the center of the hip joint through the center of the knee joint, the center of the ankle joint and hits the ground in the midline of the os calcis The axes of the knee joint and the ankle joint form a right angle with the plumb line Depending on the deformity of the leg to be treated by brace construction, we are not always able to build a brace according to this scheme of the normal We aim however, at correcting the deformity toward the normal and must therefore attempt to design the brace as close to the normal as possible There are, however, a few instances in which an exception to this rule is not only permissible but desirable, and where we use the mechanical result from an incongruence of anatomical and artificial axes to obtain a desirable change of the weight-bearing alignment of the extremity Such effects are widely used in the construction of artificial limbs to facilitate motion and to increase stability, and they are similarly useful in the building of leg braces If, for instance, in a long leg brace the position of the knee joint coincides with the anatomical axis, there will be no difference in the relationship between the lower leg and the brace, whether the knee joint is extended or flexed If, however, the brace knee joint is placed posterior to the anatomical joint when the knee is extended, flexion of the knee will introduce a force which extends the lower-leg or distracts the knee joint and which pushes the tibia anteriorly If an unweighting brace of the Hessing type is built with the knee joint placed posteriorly, flexion of the knee will move the thigh section of the brace toward the abdomen, thereby continuing the pressure against the tuber ischii in the non weight bearing phases

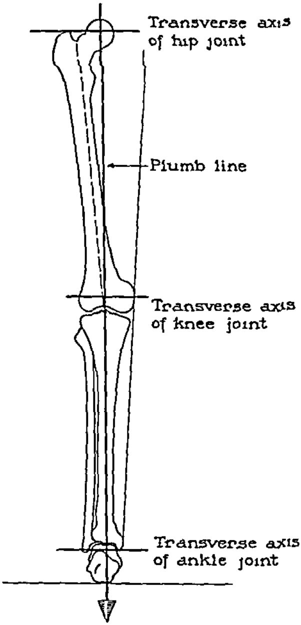


FIG 54 Axes and plumb-line of the lower extremity.

From the foregoing it is apparent that proper placement of the joints of a leg brace constitutes a major problem in the construction of these appliances At the same time, we must consider every joint of a brace as a complicating factor for two additional reasons.

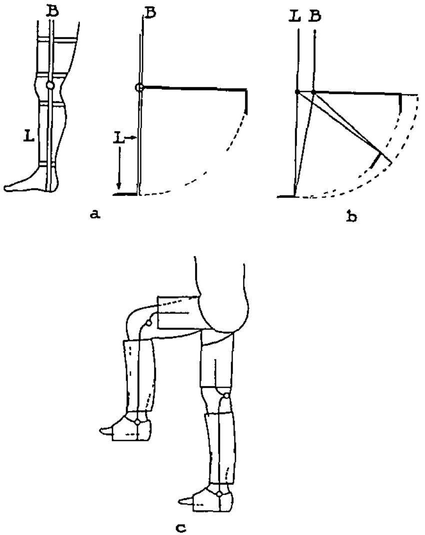


Fig 55 (a) The axis of the knee joint of a leg brace coincides with the natural axis of the knee The relative position of lower leg and brace remains the same when the knee is flexed (b) The knee joint of the brace is placed posterior to the axis of the knee joint of the leg When the knee is flexed, the lower leg section of the brace, to which the foot is firmly attached exerts traction in the direction of the longitudinal axis of the lower leg and pushes the tibia forward (c) If the knee joint of an unweighting ischial seat brace is placed posterior to the axis of the natural knee joint, flexion of the knee (with the lower leg and foot section fixed) moves the thigh section toward the pelvis (From Hans von Baeyer *Grundlagen der orthopadischen Mechanik*, Berlin, 1935, courtesy Julius Springer)

1 A joint is a weak spot To stand up under the stress of weight bearing and motion, it demands sturdy construction and this increases the weight of a brace

2 Proper construction of a joint entails a considerable amount of labor and this increases the expense of the brace Elimination of one or more joints in a brace increases its stability and life, decreases its weight and cost, and facilitates its construction It is therefore worthwhile to analyze each case to determine whether the brace must have a

knee joint and an ankle joint or whether it might be equally or even more useful without one or both joints This decision will depend upon many factors including the indication for the brace the general condition of the patient his occupation and his environment A middle aged heavy weight farmer engaged in physical labor in rough country far from a brace shop and financially unable to afford two braces will be much better off with a jointless brace A child with infantile paralysis having a fair quadriceps but with a flaccid and severely deformed foot will derive no benefit from an ankle joint which he cannot control by muscle power His brace would require only a knee joint The smaller the patient the less he is inconvenienced by lack of joints In designing a pair of leg braces for a patient with both legs affected by infantile paralysis or hemophilic arthropathy it is frequently a good plan to build the brace for the weaker leg for stability without joints and to brace the better leg for locomotion with joints and if necessary elastic or spring substitutes for muscle power To emphasize this point *joints should be eliminated wherever possible without interfering with the usefulness of the appliance* This holds especially true for the hip joints In the majority of cases we shall be able to dispense with a pelvic band or frame as well as with a link connecting the thigh brace with a spinal brace If such a connection is required it will not be possible to place the joint coincident with the anatomical axis of the hip joint it will have to be placed on the outer aspect of the leg at the major trochanter In some instances a hinge permitting flexion and extension of the hip joint will suffice in others movements in two planes are necessary to combine flexion and extension with abduction and adduction An attempt to construct a large appliance incorporating a spinal brace and one or even two leg braces will confront us with a very difficult mechanical problem and will often necessitate a good deal of experimentation before a more or less satisfactory solution is found Every type of material and brace construction can be connected with links joints and locking devices with artificial quadriceps" and gluteal straps to enable an otherwise completely helpless person to become independent of help and lead an almost normal life The series of eight photographs in the Frontispiece illustrates this point

In very rare instances a joint may be introduced that is entirely artificial and does not correspond to any of the physiological joints as for example a swivel joint on the sole of the foot to permit easy rotation of the entire leg

The construction of braces for the lower extremities will vary according to the type of leg brace to be used and the materials of which it is made We shall limit this discussion to the main examples of orthopedic appliances for the lower extremities all of which are designed to support or unweight the entire leg If these basic functions are not required in the individual case it is easy to apply the construction principles according to the indication and eliminate the parts which are not needed To give an example we would build a brace for the support of a foot and lower leg following an arthrodesis of the ankle joint according to the principles of a standard Hessing type brace for the entire leg omitting the knee joint and the thigh section and of course the ankle joint which would be entirely out of place in a case of arthrodesis

Common to all leg braces are the supporting bars which brace the extremity on one or both sides running parallel to the longitudinal axis of the extremity Forged of high carbon tool steel stainless steel or aluminum these bars carry the joints at ankle and knee and are connected with each other by semicircular bands generally made of sheet steel Both longitudinal bars and the transverse connecting bands form the steel skeleton of the brace Finally we have for the majority of leg braces a connecting link with the ground a patten a sandal or a stirrup or caliper attachment to the shoe

There are two distinctly different techniques for combining these fundamental elements in a leg brace and fitting them to the extremity The first method is characterized by two longitudinal supporting bars, fixed to each other and to the extremity by means of a number of bands which circle the limb, one half being rigid and the other consisting of a flexible strap fastened with a buckle As a rule, two bands are employed for the lower-leg and two for the thigh This apparatus is called the double bar brace While this is most commonly used, it is beyond doubt inferior to the molded leather steel skeleton construction known as the Hessing brace Certain advantages, however, explain its popularity The most obvious advantage is its simplicity It requires no plaster of Paris model It is made to measurements of the patient, supplemented, as a rule, by a tracing of the contour of the extremity and sometimes by a tracing with the aid of lead tape Prefabricated material may be used to assemble the skeleton or framework of the brace and a first fitting may take place very soon after the patient has been measured At the time of the first fitting, the brace must be carefully adjusted This requires skillful use of bending irons or pliers After the fitting, the brace may likewise be quickly lined, trimmed and finished Thus, this type of brace affords great saving in labor, time, material, and cost The fact that it covers only a small part of the body surface may occasionally constitute an additional advantage

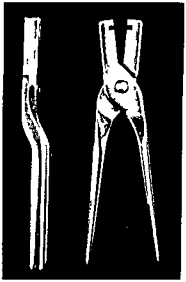


FIG 56 Bending pliers are frequently preferable to bending irons (Courtesy Alfons R Glaubitz)

The disadvantages of this brace in comparison with the Hessing type brace are self evident It requires a much heavier construction, and the forces which it generates to hold the extremity in the desired position are concentrated on a smaller surface, a factor that increases the danger of pressure sores Finally, it is much more difficult to secure a firm hold on the extremity for fixation and immobilization with a brace which consists of two bars and two narrow transverse bands than with a casing of leather, molded to a plaster cast of the body

Certain technical details must be observed when making a double bar leg brace The two longitudinal bars must be rigidly connected with a sufficient number of transverse steel bands, especially in the neighborhood of joints and at the upper end of the brace The metal parts, which are in contact with the skin, require padding and lining This type of apparatus is frequently used as a caliper into the shoe Such a caliper makes a special ankle joint unnecessary It introduces motion, however, at an artificial joint with an axis that is incongruent with the axis of the natural joint Furthermore, it converts the shoe into a part of the brace, a technique to which there are many objections The use of a stirrup in the shoe shares the latter disadvantage but permits the use of an ankle joint at the correct site

Now that we have indicated the main drawbacks of the double bar long leg brace, we must recognize its widespread use and review its manufacture accordingly

MANUFACTURE OF A DOUBLE BAR LEG BRACE

By Alfons R Glaubitz

The Tracing

A sheet of paper is used that is large enough for a tracing of both legs and the pelvis even though a tracing of only one leg may be needed The patient is placed on the paper with toes pointed up The pelvis is leveled by bringing the anterior superior spines into the horizontal plane Any abduction or adduction contracture found should not alter the position of the pelvis and the legs are to remain in abduction or adduction while the tracing is done

The tracing begins at the side of the iliac crest with the pencil held perpendicularly The contour of the side of the greater trochanter should be traced correctly as it may vary greatly from one side of the pelvis to the other The tracing is made downward with a slight pressure against the skin to achieve a good replica of the head of the fibula and the lateral aspect of the calf Any pronation or supination of the foot must be corrected The foot must also be held at a right angle when the turn is completed On the medial side the medial contour of the thigh must be recorded The skin of the thigh must be lifted as the fleshy part of the thigh tends to flatten out with the patient in the supine position The tracing of the leg is completed at the level of the gluteal fold A side tracing of the pelvis and leg should be routine procedure It will give the technician in the brace shop a pattern of the contour of the entire leg when he prepares the bars for the braces In the presence of a rigid equinus deformity or flexion contracture of the knee or hip a side tracing is essential

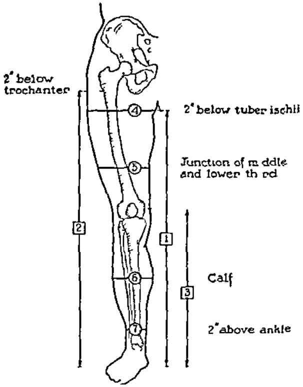


FIG 57 Measurements required for a leg brace [1] [2] [3] are longitudinal measurements (4) (5) (6) (7) are circumference measurements

Length Measurements

With the pelvis in the horizontal plane and the foot held at a right angle there must be a check for leg length discrepancy To determine if this exists the tape measure is placed in the sulcus of the anterior superior spine and along the medial aspect of each leg to the sole of the foot If one leg appears to be shorter measurements must be rechecked as this may be caused by adduction of the limb or abduction of the limb on the other side Any real discrepancy must be noted for later reference

Next a full length measurement must be taken from just above the greater trochanter to the sole of the foot with the foot held at a right angle This measurement must be recorded on a sheet of paper and checked against the next two the length from just above the greater trochanter to the center of the knee (condyles) as well as the distance from the center of the knee to the sole of the foot with the foot held at a right angle These two measurements are to be added and compared with the full length measurement to eliminate any possible error

A common error is to make the stirrup too short it is therefore best to measure the distance from the ankle joint to the sole of the foot with the foot held at a right angle The proper location of the ankle joint is about ½ inch above the tip of the fibula Measurements for the trochanter bar should be taken with the patient in a sitting position if this is possible Here the tape measure is placed just above the greater trochanter in order to measure the distance from that point to the iliac crest After one side is completed this procedure is duplicated on the other side

Leg lengths may now be compared If there is a discrepancy the patient must stand if possible and an extension board of compensatory thickness is placed under the shorter leg

Next the technician's thumbs are placed on the anterior superior spines to determine whether the pelvis is horizontal If it is not the thickness of the compensatory board must be increased or reduced by the amount necessary to level the pelvis Where the anterior superior spines are not easily accessible the technician places his hands on the iliac crest and observes the spine for a possible lateral deviation If a fixed pelvic obliquity is present the patient is given a lift only high enough to allow him acceptable posture

Circumference Measurements

The circumference of the pelvis is taken just below the crest of the ilium as well as at the widest part just above the greater trochanter This will indicate the amount of flare in the pelvis if a flared pelvic band is needed

The circumference of the thigh is taken at the level of the gluteal fold medially following the gluteal fold to the lateral aspect just below the greater trochanter This measurement represents the circumference for the leather cuff About 1 inch below this measurement the circumference is taken for the metal band The circumference of the lower thigh is taken with the knee in flexed position just far enough away from the center of the knee so that the lower section of the thigh cuff will not interfere with the action of the tendons in the popliteal space The circumference for the lower metal band is taken 1½ to 2 inches above this measurement

It is always wise to take the circumference and width of the knee to indicate the shape of the leg

The circumference for the metal calf band is taken at the largest part of the calf If the brace is to be constructed with pins at the ankle joint for easy detachment from the shoe a second measurement is taken at the lower third of the tibia for an extra metal band to reinforce the construction above the stirrup

Layout of Joints and Metal Bands on the Tracing

The layout procedure for a double bar long leg brace varies in many ways from one workshop to another Our practice is to draw a vertical line on the tracing from the middle of the thigh through the center of the knee to the sole of the foot This reference line will show the offset of the ankle joint in relation to the knee center From measurements previously taken the height of the medial bar below the gluteal fold can be located Here a vertical line is drawn parallel to the center reference line by passing the medial condyle to the sole of the foot The length measurements from the center of the knee to the sole of the foot and from ankle joint to the sole of the foot are then located on the tracing paper Next the axes for the knee joint and ankle joint are traced as a horizontal line at a right angle to the medial reference line The metal calf band and distal thigh band are also traced at a right angle to the medial reference line It is important to make sure that the calf band is below the head of the fibula and that the distal thigh band does not interfere with complete flexion of the knee The proximal thigh band from its origin at the medial side below the gluteal fold rises slightly to the lateral side staying well below the greater trochanter Short vertical lines are then drawn at the medial and lateral sides of the knee and ankle joints allowing enough

space between the vertical line and the tracing to give freedom of movement to these joints The thickness of the metal calf band and thigh band should be considered in the layout The extension bars of the lower leg should be so arranged that the overlap of the extension bars is held far enough away from the ankle joint to facilitate good fitting procedure Where a pelvic band is used the trochanter joint must be located from measurements previously taken with the pelvic band traced at a right angle to the center reference line In the presence of a severe knockknee it may be necessary to set the axis of the ankle joint and the calf band at a right angle to the shaft of the tibia

Component Parts

As steel mills have ceased to mill "Crescent Orthopedic Steel" tool steel in an annealed condition has taken its place A corrosion resistant hot rolled pickled type 410 stainless steel is beginning to find favor with many brace makers In aluminum the Alcoa type 2024 T4 is universally used for brace components If a brace shop is not equipped to fabricate its own component parts prefabricated parts are available from suppliers

For the construction of a double bar long leg brace we may be guided by the preceding section "Layout of Joints and Metal Bands on the Tracing" for selection of the material and size of joints to be made For a patient with completely flail lower extremities or a child afflicted with cerebral palsy the lateral metal components of the brace will have to be made heavier than its medial counterparts

In addition to knee locks hip locks may be required In the majority of double bar long leg braces ring lock constructions are used The "box joint" for a ring lock is much superior to the overlap ring lock joint

The stirrup which may have to carry anterior or posterior ankle stops must be strong and riveted to a metal insole in the shoe for lasting efficiency of the ankle stop Additional length for the stirrup is required to rivet it to the sole and the metal insole

Assembly of Component Parts

A varus or valgus position of the ankle should be considered when the stirrup is bent to the tracing On the side of the deformity the stirrup will have to accommodate the slightly longer distance from the sole of the foot to the ankle joint Care should be taken that the stirrup does not rub against the shoe and also that the stirrup bars at the level of the ankle joint do not touch the bony prominence of the malleoli

In forming the leg bars to the tracing special attention must be paid to landmarks such as the head of the fibula and the medial condyle There must be careful conformance of the medial and lateral bars to the tracing above the condyles of the femur as the patient will gain his greatest support at this point In lining up the calf band the edges of the calf band must follow the contour of the side tracing to avoid uneven pressure against the calf muscles Thigh bands should be held in a vertical line in relation to each other This can be best accomplished by holding a ruler against the thigh bands to make sure they are flush with the ruler To guard against disappointment it is best to use one rivet only on each side of the brace and mark these for proper positioning at the time of the fitting The same procedure should be considered for the pelvic band

Having completed the preliminary forming of the brace parts #12 rivets for assembly at the knee ankle and hip joints are used These joints may later be redrilled for proper size

The Fitting

If the general appearance of the brace on the patient is satisfactory several tests should then be made First the proper location of the mechanical joints in relation to the anatomical joints is most effectively tested with the patient sitting If the calf band appears tight and the thigh band loose the brace is probably short from knee to floor If the reverse is true and the thigh band appears to be tight and the calf band loose the length of

the brace from knee to floor is too great With the patient still in a sitting position the length from knee to trochanter joint must be checked If the bar is not long enough the pelvic band will tilt backward and press with its lower edge against the patients pelvis If the distance between the knee joint and the trochanter joint is too long the pelvic band will tilt upward

The brace should then be checked with the patient standing Webbing straps below the knee and on the thigh make this possible The correct position of anterior and posterior ankle stops is best checked with the patient standing In a double bar long leg brace with pelvic band attached the lateral balance on which the patient will have to depend is an important check out point If more than regular abduction is necessary for a patient with completely flail hip muscles outside wedges to the shoes must be considered Finally if the brace is made out of tool steel chrome plating as well as nickel plating of the bars may be considered after the fitting is completed

Leatherwork

All cuffs and the pelvic band should be cut from stiff paper patterns which have been fitted to the brace Only a colorfast grade of leather should be selected Calf elk and russet calf are normally used For a heavier cuff aniline cowhide in a medium light weight is preferable For lining material the pearl or yellow horsehide of good quality and medium weight is most practical Fast woven moleskin is also acceptable for the lining of the cuff and pelvic band To save furniture and clothing all metal bands should be covered with a backing of the same leather as is used for cuffs Where it is too difficult for the patient to lace or buckle the leather cuffs "Velcro tape will solve this problem Velcro is a woven nylon tape consisting of two strips that lock securely together in straight or contoured shapes

Final Check Out

The final check out of the brace which closely follows the fitting procedure is supervised by the bracemaker or the orthopedic surgeon It must establish that the brace conforms to the surgeons prescription provides comfort for the patient avoids irritating pressures on bony prominences and finally serves its intended purpose After the brace is applied with the patient in the sitting position the length between knee and floor as well as that between the knee joint and the trochanter joint are again checked Similarly with the patient standing this final examination will reveal any rubbing of the stirrup against the shoe and any contact of the bars against the inner or outer malleoli Furthermore the brace must produce no pressure on the head of the fibula With weight bearing there must be enough space between the brace and the medial condyle of the femur to avoid pressure Where a pad has to be used for a valgus deformity the doughnut type is recommended The thigh cuff should fit close enough to offer good support without crowding the thigh into the cuff Its proximal border should be just below the horizontal gluteal fold The pelvic band should allow at least two inches of adjustment

The most important part of the final check out however is the balance of the brace with the patient standing Gait training cannot be started with a patient with completely flail extremities or a child with cerebral palsy before the brace is properly balanced First we control the anterior posterior balance This is done by checking the right angle or "posterior stop" for proper positioning The patient must be able to sway back to a point where he still feels secure If necessary a short extension added to the heel will act like a ski and give him the extra support he may need In the case of a slight hip flexion contracture it is wise to extend the heel of the shoe posteriorly In the sagittal plane 5° of plantar flexion are desirable If however the calf muscles are not strong enough to maintain this position the anterior or reverse stop will have to be

moved to a position which minimizes dorsi flexion

Correct lateral balance gives the patient the necessary stability for standing on the floor without support The resultant feeling of security will go a long way toward rehabilitation of the handicapped patient To provide this security, abduction of the brace may even be necessary This, of course, will tend to throw all of the patient's weight to the medial border of the sole To give him complete surface bearing of the sole on the floor, comparable outside heel and sole wedges should be added to the shoe After abduction of the brace is completed, the pelvis must again be checked to make sure that it is still level

As long as double bar leg braces are widely used, we should like to stress once more the importance of a number of points that are commonly neglected

1 Correct placement of the brace knee and ankle joints must coincide with the natural axes unless a definite indication requires non alignment of these joints

2 The longitudinal bars must be connected by two semi circular thigh bands with the proximal one connecting the top end of the longitudinal bars, and two such bands at the lower leg The forged semi circular steel bar above the ankle joint is of great importance

3 The shoe must be reinforced by a metal insole to which the stirrup is riveted

4 If the longitudinal bars are built as extension bars, they must be connected by means of a loop

5 The axis of the ankle joint must lie in the frontal plane when the foot has the correct position for weight bearing in abduction external rotation of approximately 5°

6 If the ring lock is used at the knee joint, both longitudinal bars, the external and the internal, should carry a ring lock

All double bar leg braces are built according to the principles described above for a long leg brace with a ring lock knee joint, ankle joint, and stirrup attached to the shoe There are, however, a considerable number of variations which bear brief discussion

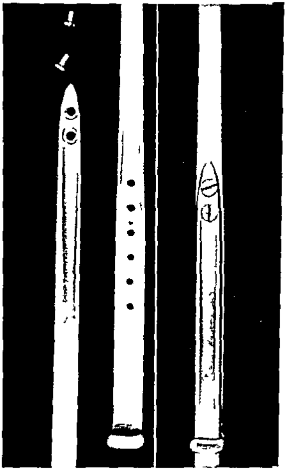


Fig 58 Extension bars must be connected with loops

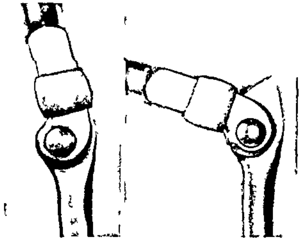


Fig 59 Ring lock knee joint

A lock is not always required at the knee joint If normal muscle power guarantees sufficient stability of this joint, a lock is superfluous This may also be the case if a mild

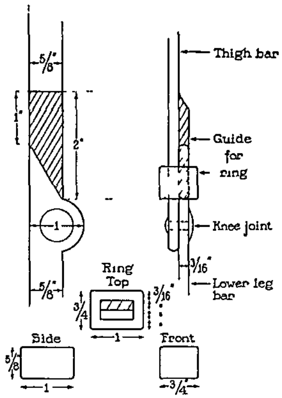


FIG 60 Working drawing ring lock knee joint for double bar leg brace

degree of genu recurvatum is present which offers stability by the position of the knee joint axis posterior to the plumb line or in the presence of an arthrodesis of the ankle joint in moderate equinus

If a lock at the knee joint is required there are a number of constructions which may be considered instead of the simple and widely used ring lock First of all the ring lock joint may be built as an automatic joint if used unilaterally on the external leg bars A spring mechanism is added to the ring which keeps the knee joint locked in extension unless the ring is pulled upward by the patient The spring mechanism consists of a steel rod ¼ inch in diameter and 6 inches long This rod goes through a guide riveted to the external surface of the thigh bar 5½ inches above the knee joint axis The distal end of the rod is articulated to the external lateral surface of the ring by a simple screw while the proximal end carries a transverse handle designed to be operated with two fingers A coil spring is drawn over the steel rod resting at the upper end against the guide and at the lower end

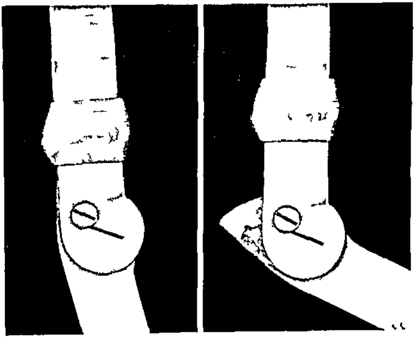


FIG 61 Modified ring lock knee joint

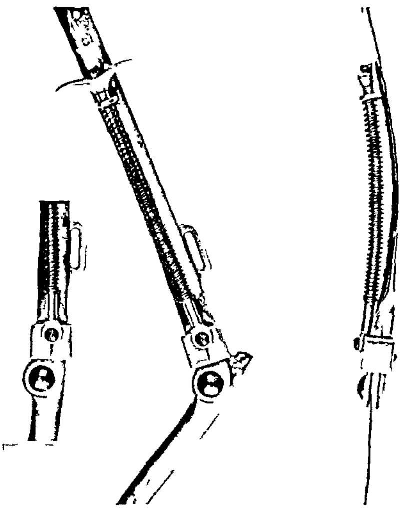


FIG 62 Automatic ring lock knee joint.

held by a rivet or bolt inserted into the steel rod In case a knee cap is used with leather straps, the bars must be fitted with metal loops to prevent the straps from being caught in the springs mechanism

We prefer, in many instances *the European O I lock joint* This represents a joint of great precision and stability As its manufacture entails a great deal of labor, it is advisable to order it from the factory, and keep a sufficient number of right and left joints in stock This device is built into the longitudinal leg bars the thigh section measuring 14 inches and the lower leg section 16 inches The spring lever mechanism for the knee lock is attached to the external surface of the thigh bar, covering approximately 8½ inches of its length The placement of a small lever operating this stop high up on the leg permits its inconspicuous management through the clothing and is also convenient for the patient who is disabled to such an extent that he cannot reach a lock at the knee joint without difficulty The great stability of this construction allows the use of a unilateral lock on the external joint of the brace only When assembling a brace with the European O I lock joint, the parts forming the lock must be taken apart and the longitudinal bars fitted to the desired contour of the extremity by hammering on the lead not by bending After the fitting has shown that the desired shape is obtained, the mechanism of the lock is reassembled and refitted to the bar, forming the long lever to the final shape of the bar Finally, a slot is filed for the stop, according to the needs of

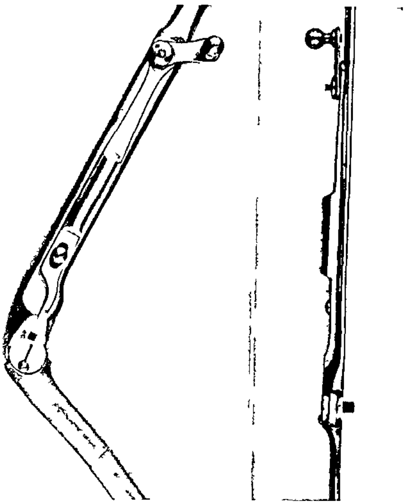


Fig 63 European O I lock knee joint for double bar and Hessing type leg braces

the individual This type of lock which may also be incorporated into the Hessing type braces and artificial legs is particularly suitable for an ischial seat brace where the longitudinal bars follow a more or less straight course at the knee joint

A somewhat simpler but very efficient knee *lock that has stood the test of time is known* among bracemakers as the Swiss lock joint" It is built in bilaterally on the internal and external longitudinal bars the short levers *locking the joints in extension are connected* in the popliteal region by means of a semicircular rod to which an elastic traction is frequently attached connecting the rod with the calf band

For double bar leg braces which have to be exceptionally rugged and constructed to be worn for a lifetime an *automatic lock joint* is sometimes used This lock joint is built as a very simple and very rigid double slashed joint The knee end of the lower leg bar is slashed in the sagittal plane forming two *halves or jaws into which the distal end of the* thigh bar is fitted thus producing large compact surfaces with the diameter of the knee circle measuring 1¼ to 1½ inches The contour *of the lower end of the thigh bar is not* a circle it has a straight edge which forms the main weight bearing stop thus relieving the lock mechanism from strain

The essential feature of the *automatic lock*

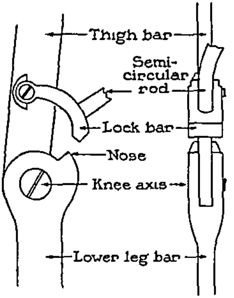


FIG 64 Swiss lock knee joint

joint is the heavy forged bolt which locks the knee by fitting deep into the joint circle of the lower leg bars The stop is forged to a thickness of ⅛ inch The part which serves as the lock proper measures approximately ⅝ inch x ⅝ inch extending in width across the entire knee joint and fitting when the knee is

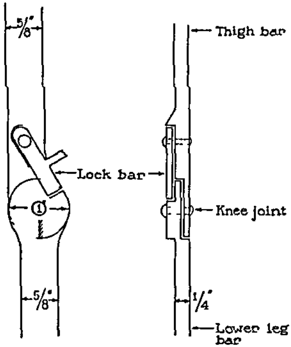


FIG 65 Working drawing Hans von Baeyers lock knee joint

locked in extension into the corresponding ¼ inch deep slot in both jaws of the lower leg bar The locking bolt slides up and down in a longitudinal slot 1⅝ inches long in the mid line of the thigh bar The bolt proper is continued from the ⅝ inch square as a ¼ inch rod up to 6 inches in length Similar to the automatic ring lock joint the guide for the steel rod is riveted to the external surface of the thigh bar 5½ inches above the knee joint a coiled spring is drawn over the rod resting against the guide at the upper end and held at the lower end by a nose which is formed where the bolt changes its shape to be continued as a ¼ inch rod Finally the square part of the bolt is secured in the slot and prevented from sliding out by a small rivet against the inner surface of the thigh bar Proximal to the guide a transverse handle is added for the operation of the automatic lock

A variation of the foot section is an attachment of the brace to the shoe by means of a caliper This renders the construction somewhat simpler but has the disadvantage of misplacing the ankle joint to the sole of the foot

Caliper and stirrup attachment share the disadvantage of having the shoe become part of the brace a construction to which there are certain objections Therefore it is frequently preferable to use a sandal connected with the lower leg bar at the ankle joint This sandal consists of a metal sole with an internal and external lateral flange for the ankle joint The foot is held in the brace by means of a lined leather sandal or at least an anklet The sandal facilitates the use of a simple stop for plantar flexion or dorsiflexion at the ankle joint

Occasionally a pelvic band must be used with a double bar leg brace in order to control rotation of the leg or to keep the pressure pad at the proximate end of the lateral upright bar close to the body as in an unweighting ischial seat brace

The pelvic band should gain a firm hold on the pelvis It must not be fitted to the patients waist as is frequently seen Its correct

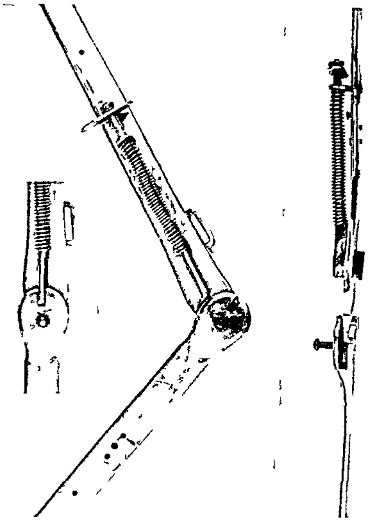


Fig 66 Automatic lock knee joint for heavy leg braces

placement is below the iliac crest A simple pelvic band is cut from 16 gauge metal 1½ inches wide and of sufficient length to reach from a point medially to the anterior superior spine of the side on which the brace is worn across the spine to the level of the trochanter or, better still, to the anterior superior spine of the opposite side The pelvic band is attached to the proximal end of the external longitudinal bar of the leg by means of a joint at the level of the trochanter This may be built as a simple hinge for extension and flexion, or as a double action joint which permits abduction and adduction in addition to flexion and extension The pelvic band is covered with calf or elk leather, lined with mole skin, and closed anteriorly by means of strap and buckle

If a patient has to wear two leg braces connected by a pelvic band this pelvic band must be made in two halves to facilitate applying and removal of the braces Instead of a hinge in the back which would have to be undesirably heavy, the left and the right halves of the pelvic band are made to overlap each other in the back with one half carrying flanges into which the other half is inserted Strap and buckle will hold the two sections of the pelvic band together We avoid the use of a pelvic band and a trochanter joint whenever

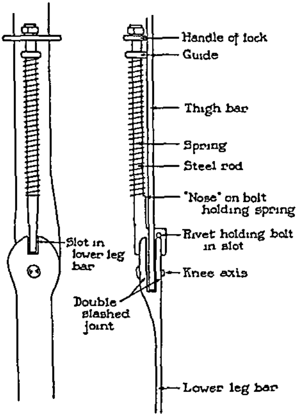


FIG 67 Automatic lock knee joint

possible The better the fitting of the leg brace the less the necessity for a pelvic band Where greater stability is required the pelvic band may be built up into a hinged lower back brace with abdominal support of elastic or coutil where complete immobilization and fixation of a hip joint are indicated we resort to a pelvic frame as used in our spinal braces

The construction of a double bar leg brace will be modified if unweighting of the extremity by means of an ischial seat is desired The von Baeyer leather strap seat is easily built into a double bar leg brace For this purpose the brace must have a lock knee Instead of the sandal stirrup or caliper attachment to the shoe, a patten may be used (see pages 112 115 6)

The double bar leg brace also may be fitted with various types of springs or elastic straps which substitute for lack of muscle power according to the needs of the individual case

Despite the great popularity of double bar leg braces of various constructions and the fact that these have been successfully used by a majority of paralyzed patients under the guidance of The National Foundation for Infantile Paralysis we must emphasize again and again that the individualized molded leather steel Hessing brace is a much superior instrument for the treatment of most patients requiring bracing for more than a limited period of time Furtherfore it is the only orthopedic appliance for the lower extremities that can be used for the rehabilitation of a hemophilia patient

With the introduction by Hessing* of the encasing molded leather steel skeleton apparatus justly known the world over as the Hessing type brace the simple double-bar leg brace should be a second choice

The arrangement of two longitudinal steel bars to both sides of the extremity in the Hessing construction is principally the same as for the double bar leg brace instead of the narrow, semi circular transverse bands which connect the longitudinal bars and hold them to the limb, the Hessing construction introduces a forged steel reinforcement unit

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* The thirteenth child of a poor potter Friedrich von Hessing born in 1839 triumphed over prejudice ridicule and opposition to become the most famous bracemaker in Germany and possibly in Europe His principal workshop at Goggingen near Augsburg was really a fashionable hotel which numbered royalty among its clientele His method of ambulant treatment for fractures of the lower extremities was first demonstrated in 1878 though its acceptance by the profession dates only from the time of the 10th International Medical Congress (Berlin, 1890) While his corset treatment of tabes at first created something in the nature of a sensation it quickly fell into neglect though the idea was later independently translated into practice by Charcot in Paris Hessing s apparatus was responsible for the popularity of conservative orthopedics in Germany and has become an integral part of the specialty as it exists today Hessing was a strange character simple one-sided and autocratic Knighted by the King of Bavaria he died at the age of eighty on March 16 1918 (see A E Stein Friedrich von Hessing und die deutsche Orthopadie Zeitschrift fur orthopadische Chirurgie 1920 *39* 9-26 with photograph)

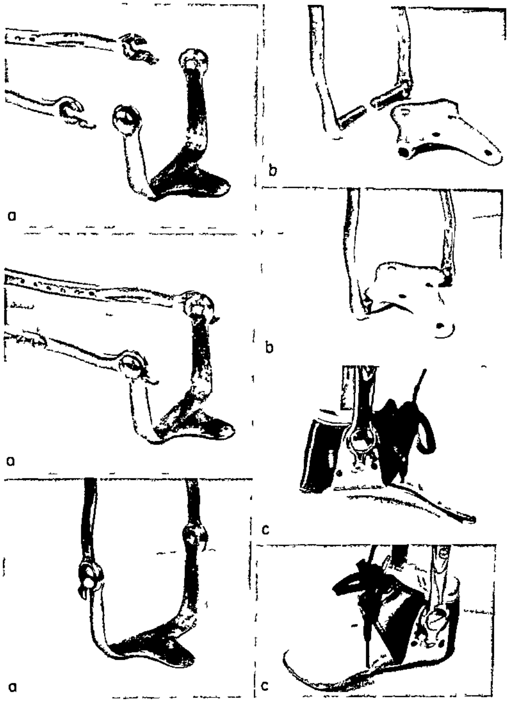


Fig 68 Foot attachments for double bar leg braces (a) Stirrup with caliper slot joint, (b) caliper, (c) sandal with ankle stop

worked into a section of molding leather which conforms in every detail to the limb, regardless of the degree of deformity which may be present. In this way, the brace gains excellent contact with the extremity without causing undue pressure, as the forces are distributed over a large surface The rigid leather case adds considerably to the stability of the brace, permitting the use of lighter supporting bars and reducing the weight in spite of the greater amount of material needed. In addition, the patient is less conscious of his brace because of the exact fitting. The conspicuous advantages of the Hessing-type brace should compensate sufficiently for the difficulties encountered in its construction.

MANUFACTURE OF A HESSING-TYPE LEG BRACE

The Plaster of Paris Model

The construction of a leg brace by the Hessing method requires the use of a carefully made plaster of Paris model. Here, we must stress the fact that a Hessing brace for the leg, more than any other type of orthopedic appliance, depends for its success upon the accuracy of the plaster model. In some instances, the negative model or mold must be taken with the leg in position for standing and walking, permitting the foot to exert some pressure on the ground.

For a correct plaster of Paris model, we recommend the use of a modeling seat, on which the patient rests with the tuber ischii of the sound side of the body, while the leg to be treated is in a vertical position and the foot is pressed against the foot rest according to the desired degree of weight-bearing. Before we proceed with the application of plaster of Paris bandages, we must determine our landmarks on the extremity with indelible pencil. The location of the axes of the knee and ankle joints, the bony prominences of the major trochanter, the patella, the tuberosity of the tibia, the head of the fibula, and the tuberosity of the fifth metatarsal bone, are thus clearly marked. We cut the

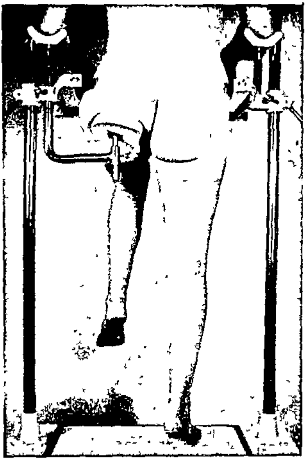


FIG 69. Patient seated in modeling frame for plaster of Paris model of right leg.

mold with a Stryker electric cast cutter over a strip of felt which is inserted beneath the plaster of Paris in the dorsal midline. We start the application of the bandages at the toes and proceed proximally to the desired level. This generally includes the major trochanter, even for a brace without an ischial seat. The model of the foot should present all the details discussed in Chapter 1, pages 8-12. We shall find, however, that in making a mold of the entire leg, especially when an ischial seat is required, we shall not be in a position to pay too much attention to the foot as we are mainly concerned with obtaining a correct model of the proximal parts of the extremity. It is therefore sometimes advisable to take a separate impression of the foot, as for a foot plate, and to use a separate model for the construction of the

foot section of the brace To obtain a good impression of the bony structures of the knee and ankle joints rotatory pressure with the palm of the hand is used in modeling the plaster to shape until it is set Plenty of plaster of Paris must be available for the modeling of an ischial seat To obtain a good impression of the tuber ischii and to insure the correct direction for the ischial seat from posterior lateral to anterior medial we make the ischial seat more prominent before applying the plaster of Paris bandage by using an auxiliary strap of webbing stockinette or a flannel bandage Removal of the plaster of Paris cast will not cause discomfort if the leg has been covered with stockinette

After the plaster of Paris is set the cast is opened and removed from the leg in the usual way taking great care to avoid breakage in the "danger zone at the ankle It is then closed with a plaster bandage and left to harden Landmarks on the inner surface of the mold are reinforced by indelible pencil the mold is rinsed with soap and water and the model is cast When the positive model is hard the negative is cut off and removed and all landmarks are immediately retraced Next the position of the axis of the knee joint most important for the construction of a leg brace is permanently marked with nails driven into the cast on the internal and external aspects of the knee leaving the heads about ½ inch outside the cast The ankle joint axis may be similarly marked if desired If an ischial seat brace is to be constructed the seat is prepared at this point plaster is scooped out at the tuber ischii until the width of the seat amounts to about an inch and the direction of the ischial seat is established from postero lateral to antero medial as mentioned above The surface of the entire cast is smoothed out and a thin coat of plaster of Paris cream is applied to fill in all uneven areas After this coat is fairly dry the cast is sandpapered and the model is ready to be used for designing of the brace

Building the Hessing Brace to the Plaster of Paris Model

(By Alfons R Glaubitz)

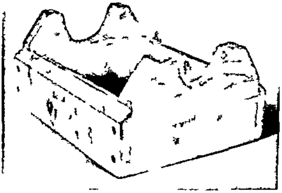


Fig 70 Cast bench used in building leg braces

The plaster of Paris model is placed on a specially prepared cast bench with the patella and toes pointed vertically upward A straight line is drawn over the entire length of the model marking the anterior midline to which the molding leather must reach Another midline is drawn on the posterior side of the model which will be helpful in determining the intersection of the bars of the steel frame units for the thigh and calf (More recent constructions show such a unit at the thigh only) These two lines will facilitate placement of the medial and lateral bars of the brace The proper location may also be determined by measuring the circumference of the thigh and lower leg at four or five different levels The medial and lateral lines however must go through the permanently marked centers of the knee and ankle

The location of the eight triangular screw plates later to be united with the steel frame units is traced on the model with the center of each plate placed on the medial and lateral lines The plates are positioned at the following levels on the upper lateral portion of the thigh about 2 inches below the greater trochanter and on the medial side about 2 inches below the gluteal fold or tuber ischii On the lower portion of the thigh brace the

screw plate is located 2½ inches medially and laterally above the knee center. This pair of screw plates must in every instance, be high enough to clear an imaginary line from the back of the calf to the thigh with the knee flexed. The proximal pair of screw plates in the lower section of the leg is placed about 1 inch below the head of the fibula on the lateral border and the medial plate is to be located at the same level as the lateral. Finally, the lower pair of screw plates is placed at the level of the dividing line of the third and fourth quarter of the distance between the knee joint center and the center of the medial malleolus.

To complete the tracing of the steel frame units, a line is drawn from the screw plate below the greater trochanter to the medial screw plate below the gluteal fold. In tracing this line the contour of the gluteal fold is followed on the lateral side to about the level of 1 inch below the tuber ischii. The line is then continued under the tuber ischii if ischial weight bearing is desired. This line slopes down to the medial screw plate 2 inches below the gluteal fold. While the steel frame unit is held lower on the medial aspect of the limb, the leather will remain at the level of the tuber ischii.

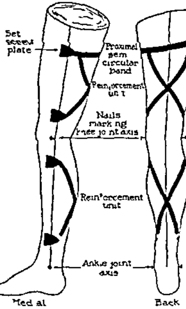


FIG 71 The steel skeleton for a Hessing type leg brace is traced on the model

From the line presenting the proximal semicircular band, two crossbars are traced down to the lateral and medial screw plates above the knee. Instead of this original design two vertical bars may be traced to the screw plates on the same side. The steel frame unit for the lower leg is traced crosswise from the pair of screw plates below the knee to the plate on the opposite side above the ankle.

In tracing the stirrup sections two thirds of the width of the distal end of the stirrup is set in front of the medial and lateral line which was traced previously. The reason for this is that with the 1 inch heel height normally used the stirrup bars will be vertical with the floor. The width of the distal portion of the stirrup is never less than 1 inch. The sole plate ends distally behind the head of the first metatarsal. At the heel it is slightly cup shaped. The longitudinal borders are held low.

This completes the designing of the steel skeleton on the plaster model. Before starting the steel work the contours must be outlined for the encasing leather parts of the brace—an essential feature of the Hessing technique. After paper patterns are made for the thigh, calf and foot sections three pieces of leather are cut accordingly using 1½ to 2 ounces molding leather with very little rawhide in it. The leather is soaked in lukewarm water overnight before it is used.

The Steel Frame Unit

The building of the brace begins with the preparation of the triangular screw plates. These screw plates are cut from 16 gauge sheet metal triangular in shape about 1¾ inches long and 1½ inches wide. The plates for the lower leg are somewhat smaller. For children these should be scaled accordingly. A small steel block about 5/16 inch by 1¼ inches is brazed or welded on the surface of the plate and fitted for five 8/32 inch screws. Two additional holes are drilled at the broad base of the plate and one at the narrow end for

copper rivets, which will connect with the component parts of the steel frame unit to which the plates are brazed or welded After each triangular screw plate is completed it is fitted and fastened with nails to the model at the proper location

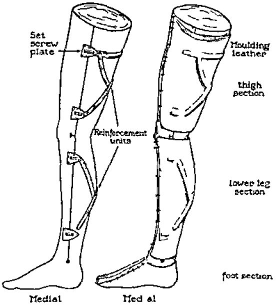


FIG 72 The reinforcement unit of the Hessing type leg brace is fitted to the model

The proximal semi circular bar for the brace is made from $^{11}/_{16}$ inch by [illegible] inch half round steel When formed to the cast the triangular screw plates are brazed or welded to this bar and the section is returned to the model If desired this bar may be forged in one piece as a combination of semi circular bar and triangular screw plates

The cross bars of the steel frame unit are made of $^{7}/_{16}$ inch by $^{5}/_{32}$ inch half round steel These bars overlap on the corresponding screw plates They are riveted together and then brazed or welded The posterior line traced on the plaster model acts as a guide so that the bars at the thigh and the calf cross in the middle of the limb Holes are drilled at the crossing for copper rivets to hold the bars at this point to the leather casing

The unit is shellacked inside and out, before it is returned to the plaster model, to

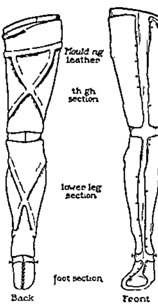


FIG 73 The molding leather is stretched over the model showing contour of the reinforcement unit

prevent the metal from rusting on the cast and under the wet molding leather As the molding leather has been soaked in water it has become swollen and stiff To make it more pliable, it is whipped against a post or doorway The leather is then carefully stretched over the model with the aid of shoemaker s pliers An edge creaser available at harnessmaker supply houses will aid in molding the leather over the steel frame unit until the steel skeleton of the unit is clearly prominent

The molding of an ischial seat for ischial weight bearing requires great care holding the leather close to the cast which has been scooped out at the tuber ischii

For the foot section the molding leather is nailed to the model on the dorsum of the foot The open heel section is closed with two harnessmaker needles (made with a dull point) and an awl When the leather sections are dry windows are cut over the small blocks on the triangular screw plates and the steel frame unit is riveted to the leather with copper rivets The heads of the copper rivets

which have already been polished remain on the outside of the leather

Completing the Steel Work

The medial and lateral bars of the brace are forged from 11/16 inch x 5/32 inch round edge high carbon tool steel decreasing toward the ankle to 5/8 inch x 5/32 inch Grinding and polishing of the bars will reduce them to about 1/8 inch thickness The lower leg bars are made as extension bars with the proximal bar running from the knee joint to just above the lower pair of set screw plates and the lower extension bars from the ankle joint to just below the upper pair of set screw plates The extension bars are held together by 8/30 inch oval head screws

The knee joints are milled as overlap joints or center milled joints These are forged to 1⅛ inches in diameter and to the thickness of ⅜ inch The specification for the straight shank mill is 7/8 inch A pilot hole is drilled to the center of the forging corresponding to the pilot on the straight shank mill The forging is milled from the inside of the thigh bar leaving about 3/16 inch thickness for the joint s surface The forging of the lower bar is milled from the outside also allowing a thickness of 3/16 inch for the joint surface After this is completed the forgings are placed one on top of the other at slightly less than a 180° angle A horizontal line through the center of the joint will determine the anterior stop of the bars The bars are then flexed to slightly less than 90° and another line is drawn from the anterior stop to the center of the knee to determine the necessary cut-out for knee flex ion Having selected the anterior and pos terior stops we use a hacksaw to cut down at these points to the joint surface All material remaining on the forging from the milling procedure may be trimmed down and the surface bearings may be fitted together

Ankle joints are forged to about ⅞ inch and milled with an 11/16 inch straight shank mill following the same milling procedure outlined above In selecting the stop only

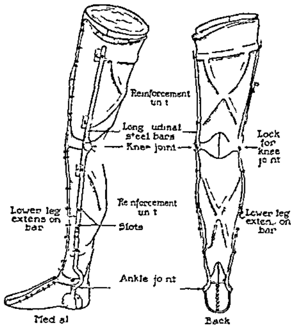


FIG 74 Hessing brace assembled for fitting longitudinal bars in place

one horizontal line through the ankle joint is drawn The filing of the anterior and poste rior stop for the ankle motion is best done af ter the brace is fitted The bolt used for this type of milled joint has a round base and a nut about 5/32 inch thick The diameter of the base corresponds to the size of the corresponding milling The shanks of the bolt are about ¼ inch to ⅜ inch in diameter and fit into the lower section of the bar The square section of the bolt corresponds in size and fits into the upper bar of the joint The thread used for this bolt is 8/30 inches (an imported bolt will carry a 6 mm thread)

The stirrup parts of the ankle joint are made of two components From the ankle joint down they increase in width toward the sole and are at least 1 inch wide All edges are beveled especially where these components are attached to the metal sole The metal for the sole plates is usually cut from 16 gauge steel A thicker gauge is ad visable for a heavy person The metal sole is hammered on lead to the surface of the leather not to the cast proper To facilitate the fitting of the sole chalk may be rubbed on the leather surface When the metal sole

is pressed against the surface of the leather the chalk shows the high spots of the plate which require further adjustment

Next the medial and lateral bars are slotted for $^{8}/_{36}$ inch screws and fitted to the thigh and lower section of the brace Beginning at the knee joint the lower bars are fitted to the model with the knee joints in the sagittal plane of the body and parallel to each other Their connecting axis should be at a right angle to the weight bearing line

The ankle joints must also be in a perpendicular line but relative to the anatomical axis of the ankle The stirrup components are fitted over the metal sole and temporarily riveted to the sole

Locations for slots are found at the level of the screw plates and then filed into the bar for $^{8}/_{36}$ inch screws Finally the leather sections are removed from the model and the brace is assembled for fitting

Finishing the Brace

At the time of the fitting the leather sections of the thigh and lower leg are trimmed to about 1 inch anteriorly to the steel bars This will enable the patient to apply the brace without discomfort The lower posterior section of the thigh cuff is trimmed to give freedom in the popliteal space in the sitting position Likewise the free play of the patella should not be disturbed

The upper portion of the lower leg encasing is trimmed in the back to permit full flexion of the knee In front it should include all of the tuberosity of the tibia At the ankle the leather is trimmed anteriorly and posteriorly to permit flexion and extension of the foot Care must be taken to avoid pressure over the tendo Achillis The foot section is trimmed to include the head of the first and fifth metatarsals On the dorsum of the foot the molding leather should be cut back generously to reduce the bulk of the sandal and permit easier fitting within the shoe Next paper patterns are cut for the three lacer strips The brace is then taken apart and the

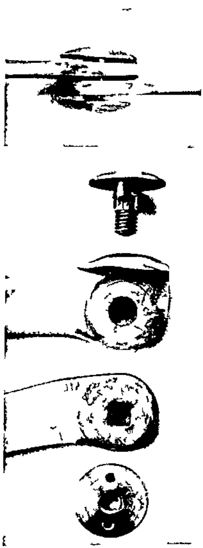


FIG 75 Knee joint for Hessing brace

steel bars are nickel plated and chrome plated After all edges of the leather sections are skived the component sections are cleaned with a thin solution of oxalic acid and polished with a dry cloth If an ischial seat is used it is covered with an adequate felt pad

The flaps that are to cover the open space on each of the three sections are cut from four to five ounce strap leather skived and sewn to the inside of each section on the medial side The eyelet strips are cut to about 2 inches in width lined with horsehide and fitted with eyelets that are no smaller

than size A The lateral strip is sewn to the leather section and the medial strip to the flap A 1½ inch draw space will be sufficient between the two leather strips

The brace including the flaps is now lined with chamois or horsehide If necessary for an individual case a buckle and strap may be fastened at the proximal end of the thigh and lower leg sections to reinforce the lacing at these points

The stirrup section is then riveted to the metal sole After the foot section is lined and completed with eyelet strips it is riveted to the metal sole All rivets are countersunk to avoid marks from the rivets on the inside of the shoe

MODIFICATIONS OF A HESSING BRACE

The foregoing description covers the original construction of a Hessing brace There are various minor alterations which may adapt it to the needs of the individual patient Here however it is essential to discuss one major modification which has gradually been developed for the specific use of the hemophiliac

The Hemophilia Hessing Brace

Anyone able to build the original Hessing brace according to the instructions given on the preceding pages can certainly construct this new modification We shall therefore indicate only wherein it differs from the original design

Designated as the *Hemophilia Hessing Brace* this modified appliance eliminates the steel reinforcement unit in the back of the thigh and calf sections as well as the triangular screw plates but retains the original extension bars The resultant design is simpler to manufacture lower in cost and lighter in weight For hemophilia patients frequent changes in the volume of the thigh and lower leg are characteristic of the disease after hemorrhages and during periods of rehabilitation At such times it is far better to make plaster of Paris models for new molded leather sections Not only is this more accurate it is also safer than the older method of adjusting calf and thigh sections by means of triangular plates and screws a procedure which involves the risk of trauma in hemophilia

This discussion of modifications of the Hessing brace would not be complete unless we stressed here certain additional factors which contribute to the success of this appliance

The joints in a Hessing brace are of the greatest importance as the usefulness of the brace depends to a large extent on their proper location and stability Moreover the joints are more subject to wear and tear than any other part of the brace Therefore only milled joints described on page 99 should be used in connection with the Hessing type leg brace Screws must be carefully tightened in order to guarantee large surface contact and they must be oiled at regular intervals Furthermore they must be inspected by the bracemaker from time to time so that worn out bolts may be replaced before the entire alignment of the brace has been damaged

At the knee joint a lock may be necessary just as in a double bar leg brace For the Hessing type brace we recommend the use of the *Swiss lock* or one of the other constructions which we described for the double bar leg brace If the knee joint should remain locked in extension for a limited period of time a separate fixation bar may be used bilaterally bridging over the knee joint and connecting the longitudinal steel bars rigidly above and below

Lofstrand and Schleeker Constructions

Introduction of Lofstrand brace constructions during World War II offered an entirely new design of the knee joint Using a double knee joint with or without springs and occasionally with a knee lock in connection with the original Hessing braces this concept in brace construction marked a new era especially for the rehabilitation of hemophilia patients Spring joints permitted a wide range

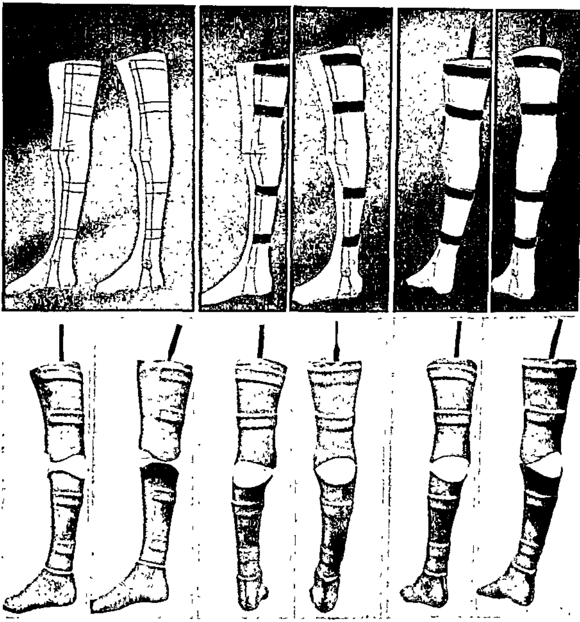


FIG. 76. Manufacture of a pair of hemophilia Hessing braces from plaster of Paris model to finished appliance.

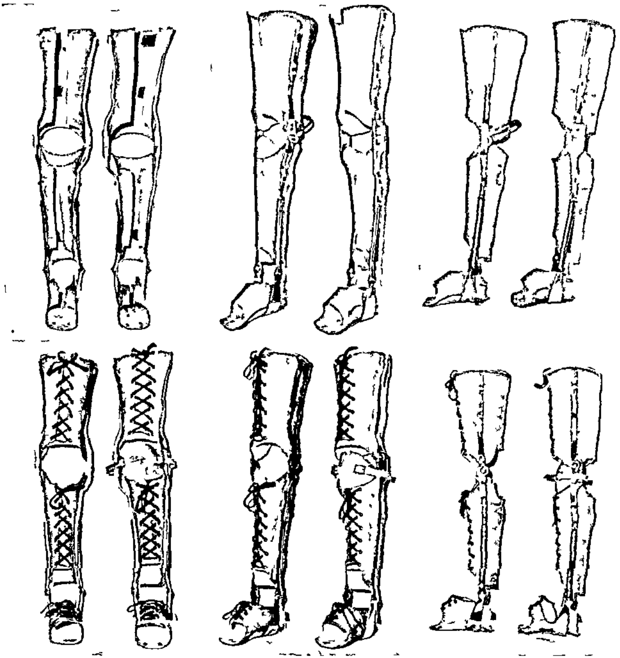


FIG 76 (cont'd) Swiss lock knee joint on the right Schleeker knee joint on the left milled ankle joints right and left, knee cap shown only on left knee

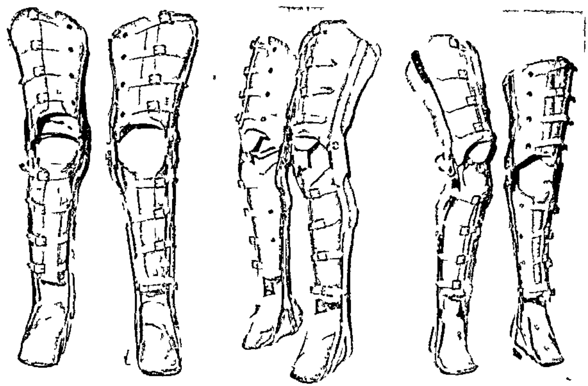


FIG 77 Hemophilia Hessing brace for advanced hemophilic arthropathy of right and left knees complete bony ankylosis of right and left ankle feet in marked equinus position Ankle joints omitted Swiss lock for right knee permits patient to drive car Compensation for equinus deformity incorporated into foot section of brace

of motion as well as a degree of spring tension necessary to help the weak quadriceps extend the knee joint without the need for the old type of external or artificial quadriceps to be described later on

When the Lofstrand braces and their highly efficient spring joints disappeared from the market our bracemaker Paul Schumacher with the aid of Paul Leeker devised the Schleeker spring joint a new and different spring joint for the knee Its design and therefore its manufacture are much simpler than for the Lofstrand joints and it is less bulky—a decided advantage for patients who must wear two long leg braces The springs may be obtained in different strengths and are easier to replace than those used in the original Lofstrand joints If the knee with the Schleeker spring joint must be temporarily locked in extension the spring can be replaced with a bolt

Hessing braces with Schleeker knee joints are now standard for hemophilia patients Many of these cases must depend upon their Hessing braces even if flexion deformities of the knees have not been corrected to complete extension of 180° Some patients can walk satisfactorily with extension of 165° It is often necessary to lock the knee temporarily at the angle of maximum extension for the patient This angle may be gradually increased as rehabilitation progresses To accommodate these patients and eliminate the need for frequent trips to the brace shop the Schleeker knee joint has been fitted with a series of external locks that are simple for the patient to manage This means that a hemophilia Hessing brace may be delivered with a series of

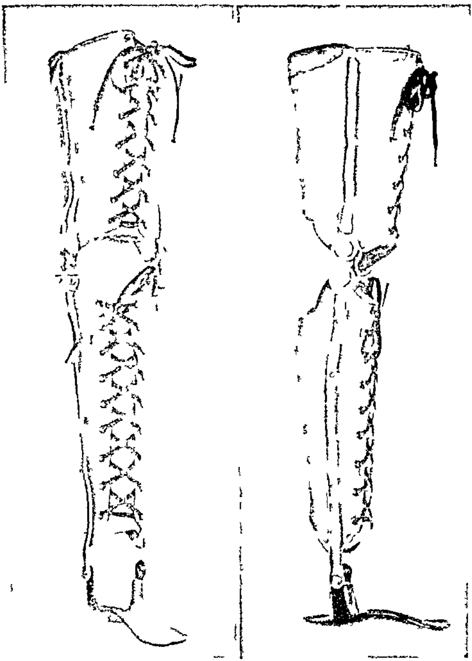


Fig 78 Hemophilia Hessing brace with Lofstrand spring joints at knee milled ankle joints no sandal

exchangeable locks to hold the knee at an angle of 160°, 165°, 170° and 175°

Manufacture of the Schleeker Spring Joint

By Paul R Schumacher

The body or box of the joint, measuring 2 [illegible] inches x 1 1/4 inches x 1/2 inch is made of 24 S T aluminum A [illegible]/16 inch hole is drilled throughout the length of the block at a distance of 1/8 inch from one side as shown in Figure 81 With a milling machine or a mill cutter attached to a lathe slots as shown by the dotted lines in Figure 81 are cut in the aluminum block from both sides A 5/16 inch mill is used for adults and a [illegible]/16 inch mill for

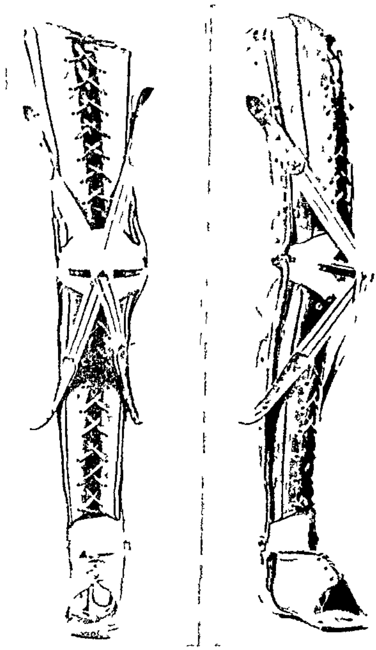


Fig 79 Hessing type long leg brace with artificial quadriceps

children *The upper and lower bars, measuring* $\frac{1}{4}$ inch x $1\frac{1}{4}$ inches for adults and $\frac{3}{16}$ inch x $1\frac{1}{4}$ inches for children, are fitted into these slots They are shaped exactly to the diameter which has been milled out with a *tang* added on the back edge of the bars to accept the pressure from the springs

The springs are made of flat spring steel or square edge steel They are wound as compression springs to clear the $\frac{5}{16}$ inch hole cut throughout the length of the block For the ends of each spring, $\frac{5}{16}$ inch bearings are needed A template for drilling the center rivet holes is recommended

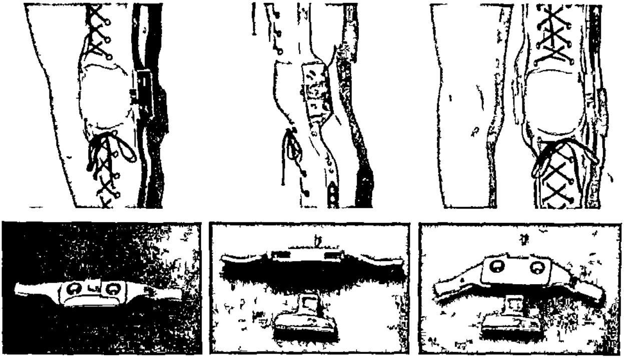


FIG 80 Schleeker knee joint with a series of three locks that are used to obtain a gradual increase of extension at the knee

To assemble the Schleeker spring joint one bar is riveted to the box One of the bearings is inserted followed by the spring which is 2¾ inches long The second bearing is placed on the spring and the second bar is riveted in place It takes considerable pressure to compress the springs until the rivet holes are lined up so that the second rivet can be positioned A pair of these locks is needed at the knee joint of the Hessing brace

To lock the knee joint at an angle between 160° and 175° a series of external exchangeable locks may be used according to medical indication These locks are built as a clip covering the center of the joint This lock is attached with a single screw into the center of the anterior aspect of the joint

An additional joint may become necessary if a Hessing type leg brace is used in connection with a pelvic frame This type of joint is located at the level of the greater trochanter at the external aspect of the brace in line with the external longitudinal thigh bar hence the name "trochanteric joint" The trochanteric joint may be constructed as a simple hinge for extension and flexion at the hip joint or as a double action joint permitting motion in two planes namely flexion and extension plus abduction and adduction The trochanteric joint must be milled and the bars which form this joint connecting a pelvic frame with a long leg brace require greater strength than the rest of the steel skeleton be

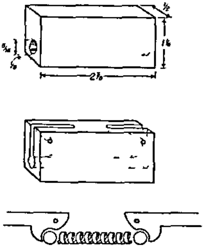


FIG 81 Working drawing illustrating Figure 80

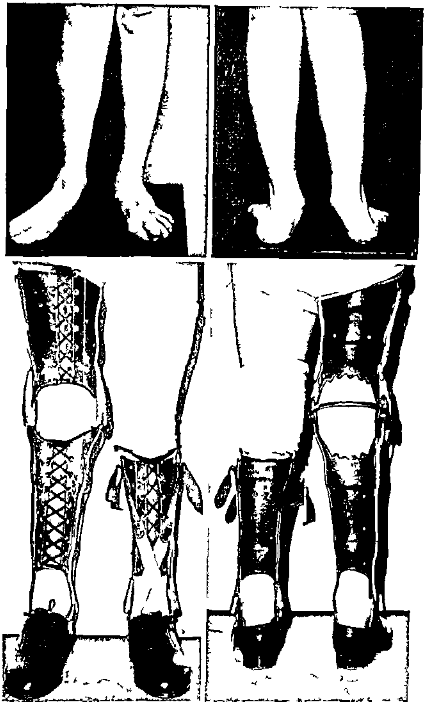


FIG 82 Right A long leg Hessing brace with Swiss knee lock no ankle joint Left Hessing lower leg brace with ankle joint and elastic straps for severe paralytic deformity

cause they are subject to an unusual degree of stress and strain An indication which necessitates the use of a trochanteric joint frequently calls for the construction of fixation devices or for the introduction of corrective forces as in the case of an adduction contracture This has led to a great number of special constructions which may be used according to the requirements of the individual case

The Artificial Quadriceps

A Hessing type leg brace is a suitable apparatus for the use of a so called "artificial quadriceps" which may compensate for a weak or paralyzed quadriceps muscle As we have said the Lofstrand and Schleeker spring joints for the knee represent an almost ideal

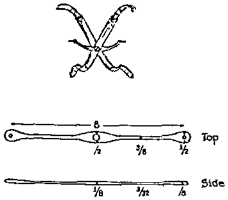


FIG 83 Construction details of "artificial quadriceps"

solution of this problem Where these joints are not available however an artificial quadriceps may be made of two elastics ¾ inch wide which cross on the anterior aspect of the leg in front of the patella To gain the momentum necessary to introduce a force extending the knee joint the lever must be increased by leading the elastics over a bridge formed by a semi-circular bar which connects the knee joint at the brace

Manufacture of the "Artificial Quadriceps" A semi circular bar is forged from ½ inch x ⅛ inch round edge high carbon tool steel The bar keeps its maximum width of ½ inch in the anterior midline just in front of the patella It is forged narrower and lighter in the quarter circle between the midpoint and the axis of the knee joint to about ⅜ inch in width and 3/32 inch in thickness in order to obtain the necessary spring Each quarter circle regains almost the width and thickness of the anterior part at the lateral end where the semi circular bar is fitted with pins to be inserted into drill holes on the inner aspect of the caliper bolts The bar is hammered to the shape of a semi circle the radius of which corresponds approximately to one fourth of the distance between knee joint and ankle joint It is important that the semi circular bar is hammered and not bent The elastic straps are attached crosswise to the middle of the semi circular bar by a flat head screw The four ends are fitted with straps which are fastened to studs on the longitudinal steel bars of the brace just above and below the distal and proximal pair of set screw plates respectively

The Pelvic Frame

While the Hessing type leg brace usually does not require the use of a pelvic band a pelvic frame may be used if the patient s condition calls for fixation of the hip joint The pelvic frame is built to a plaster of Paris model of the body following the principles set forth for the construction of the pelvic frame of a spinal brace This is true for the plaster of Paris technique as well as for the tracing and the manufacture of the pelvic frame (see Chapters 1 and 2) The building of the pelvic frame is facilitated if a separate plaster of Paris mold is made for this section of the brace The two half sections of the pelvic frame are again connected in the back with a double frame hinge (von Baeyer) which materially adds to the stability of the pelvic frame connected to a leg brace

The steel skeleton of the pelvic frame should be assembled when the brace is fitted When its correct fitting to the pelvis is assured we are confronted with the problem of connecting the pelvic frame with the leg brace To determine the proper location of

the trochanteric joint and the course of the trochanteric connecting bar which holds the leg brace to the pelvic frame, it is advisable to determine the relative position of both sections with the plumb line.

The trochanter connection bar is built as an extension bar. The section below the trochanter joint is fitted to the external longitudinal thigh bar and held in place by means of a slot and screws. Occasionally, additional holes in the proximal lateral set screw plate (in the thigh section of the leg brace) are provided. This set screw plate is then built larger than the others. The proximal section of the trochanter connecting bar which is attached to the pelvic frame, must be shaped according to the contour of the body in the hip region between the horizontal trochanteric and iliac bars of the pelvic frame to which the connection bar is screwed.

To compensate for a rotatory tendency of the pelvic frame when connected with a long leg brace, countertraction is applied on the opposite side by means of a perineal strap.

THE ISCHIAL SEAT AND UNWEIGHTING OF THE LOWER EXTREMITIES

Many of the indications for an orthopedic appliance for the lower extremities call for unweighting of the entire leg including the hip joint. From what has been said about the anatomy and physiology of the lower extremities, it might appear a simple problem to exclude weight bearing, as nature has provided an ideal support for the body weight in the sitting position: the tuber ischii. It would only be necessary to transfer the weight from the tuber ischii to the ground in order to eliminate weight bearing from the bones and joints of the leg. It is true that the anatomical structure of the tuber ischii and the soft parts covering the skeleton in this region furnish an adequate support for the body weight and a suitable point of action for a brace. Nevertheless, unweighting the lower extremity at the tuber ischii presents a number of problems which deserve detailed discussion.

The principle involved is a simple one. Instead of standing and walking on his leg, the patient must sit on a brace which transmits the body weight from the tuber ischii to the ground. The part of the brace which carries the body weight at the tuber ischii is called "ischial seat." The ischial seat of the brace must conform to the shape of the tuber ischii and must fit the body firmly and in such a way as to prevent the tuber ischii from sliding down from the ischial seat of the brace and moving away from it in the non weight bearing phases of the gait. At the same time, the construction must avoid all possible discomfort and inconvenience to the patient. This may be caused by the bulk of the brace on the inner aspect of the thigh toward the perineum, or by the pressure of the brace when the patient is sitting down. The patient may also find it difficult to keep this part of the brace clean. Finally, considerable bulk at the proximal end of the brace cannot always be avoided and may be very cumbersome, especially for an obese patient.

As to the brace construction in general, we have to keep in mind that unweighting of the lower extremity at the tuber ischii necessitates the elimination of undesirable weight bearing contact throughout the entire length of the extremity. In other words, if the weight is to be transmitted from the tuber ischii to the ground, the brace must not transmit the counter pressure of the ground to any part of the leg as would be the case if the brace were to fit tight above the femoral condyles or below the knee, or if the heel were to be supported by the foot part of the brace.

For the same reason, sufficient length must be added to the leg measurements when the appliance is constructed as a double bar leg brace. As a rule, a $\frac{3}{4}$ inch addition must be made to the measurement of the leg from the knee to the ground to provide the unweighting as the "non weight bearing zone" of the brace is added to the lower-leg section and not to the entire length of the brace.

In discussing the different types of ischial seat constructions, we have to mention the

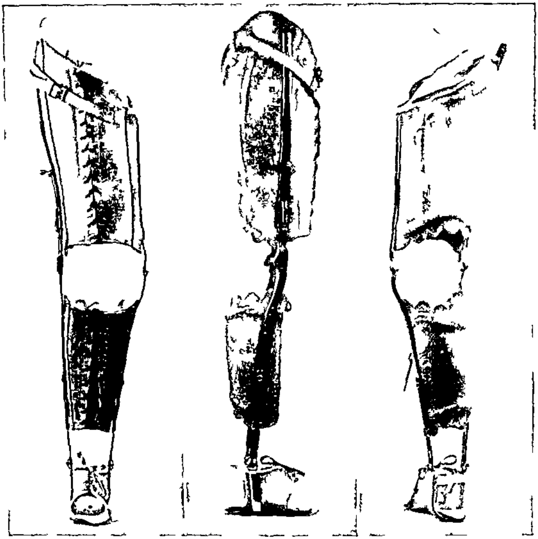


FIG. 84. Hessing type long leg brace incorporating ischial strap seat and knee lock with lever action.

Thomas ring originally devised by Hugh Owen Thomas * for the unweighting of a tuberculous knee joint. This has been widely used in the construction of unweighting double bar leg braces.

Unweighting of the lower extremities is most efficiently achieved by the *Hessing type ischial seat brace* provided that the construction of the ischial seat and of the encasing molded leather thigh part of this brace is correct. This will depend almost entirely on the plaster of Paris cast to which the brace is constructed. The original ischial seat of the Hessing type brace was an integral part of the appliance. This made adjustments and alterations technically difficult when the patient gained or lost weight or when the shape

* The "Thomas ring" was designed by Hugh Owen Thomas of Liverpool (1834-91) sometime between 1868 and 1872, primarily for afflictions of the knee joint, though it was later used to treat fractures. There were three original forms of the splint: the bed splint, the patten-ended knee splint and the caliper splint. In his classic monograph *Diseases of the Hip, Knee and Ankle Joints*, 2nd ed., Liverpool, 1876, pp. 82-4, Thomas mentions that he first applied his splint to an adult (a case of long standing chronic inflammation of the knee joint) in January 1869, having used it for children some years previously.

of his thigh changed for other reasons All these difficulties were eliminated with the introduction of the ischial strap seat to be discussed on pages 114-5 *This may be used with* equally good results in connection with a double bar leg brace or with a Hessing type brace

THE "SITZSTOCK" (ISCHIAL SEAT CRUTCH)

The idea of transmitting weight from the tuber ischii to the ground by means of a leather strap under the tuber ischii was conceived by von Braeyer in 1917, during World War I, with construction of the Sitzstock" (ischial seat crutch) to avoid the disadvantages of crutches and, at the same time, to enable the patient, after amputation of a leg to be up and about long before an artificial leg could be fitted and delivered This appliance, *which was successful in hundreds of* wartime cases was also effective as an orthopedic appliance for time limited use in the treatment of conditions of the lower extremities which required unweighting of a leg without the necessity for immobilization The so called "Sitzstock or ischial seat crutch for the unweighting of a lower extremity, including the hip joint is indicated in cases where the patient must walk as soon as possible without weight bearing on the leg This may be advisable when an unweighting leg brace is required but not yet available, or for conditions which do not require a brace for con

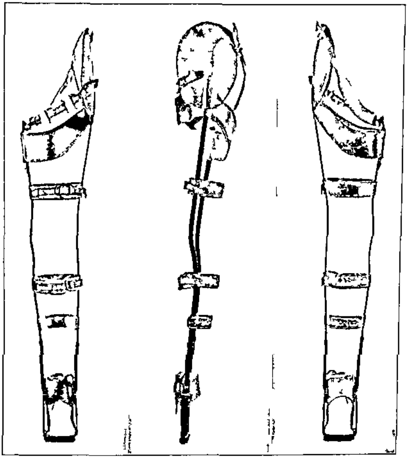


FIG 85 Jointless double-bar ischial strap seat brace with Patten"

Fig 86 "Sitzstock" (ischial seat crutch)

stant wear but which need unweighting for short periods of time It is also designed for patients who must be gradually accustomed to weight bearing These are the patients normally allowed to get up with crutches

Because crutches have a number of very definite disadvantages their use should be eliminated whenever possible One of these disadvantages is their adverse psychological effect many patients think themselves cripples when they have to rely on crutches On the other hand a great number of patients especially the neurotic type will become crutch addicts so that it may be very difficult if not impossible to free them from the use of crutches Moreover crutches require the full use of both arms and if used over a long period of time the function of the arms may be impaired by trauma to circulation and nerve supply caused by pressure of the crutches in the axillae Hemophilia patients invariably develop hemorrhages and arthropathies in the shoulder when forced to use crutches They cannot benefit from the "Sitzstock and have to use a wheelchair or a lightweight folding walker until their specific orthopedic appliances become available Finally the use of crutches does not guarantee complete unweighting for example of a diseased hip joint Therefore if the patient is not sensitive he may submit his leg to undesirable weight bearing without being aware of it

With the "Sitzstock properly applied the patient is enabled to walk about in the same manner as he would with an artificial leg (without knee joint) or with an unweighting ischial seat brace The "Sitzstock" is easily applied and if worn under the clothing is only slightly conspicuous

The appliance consists of a stilt or crutch made of light wood the ischial seat strap the shoulder strap and one or two straps for the leg The details of the appliance are readily understood from Figure 86 The proximal part of the wooden stilt or board is cut sufficiently wide to rest well against the outer aspect of the pelvis and the thigh It tapers off toward the distal end which is shaped like an ordinary crutch carrying a rubber cap In the hip region the board is shaped concave to conform to the contour of the thigh Although this is not absolutely necessary, it

adds to the patient's comfort and prevents rotation One or two pads may be placed between the board and the thigh, for instance at the level of the trochanter and above the condyles at the knees, depending upon the configuration of the patient's legs The shoulder strap, which runs across the opposite shoulder, is attached to the wooden board by means of screws The board carries oblique slots for the ischial seat strap and the thigh strap It may be equally used for a left or a right extremity This simple appliance may be kept in stock in only a few sizes It may be cut at the distal end to the length of the patient, with the finer adjustments being made by varying the length of the ischial seat strap and the shoulder strap If unweighting of a leg, which presents no shortening, is desired, the shoe of the other leg must be raised exactly as with an ischial seat brace

The patient rests comfortably on the flexible ischial seat formed by the strap, with the board following the movements of the legs *by means of the shoulder strap and the thigh* strap or straps but without the aid of the hand

The use of this appliance is particularly recommended for unweighting the hip joint or the femur, following fractures and conditions such as Perthes' disease There may also be a wide range of indications in the after care of various operations on the leg following the removal of a plaster cast and prior to the application of a brace

UNWEIGHTING LEATHER STRAP SEAT

If an appliance for unweighting of the entire leg is to be constructed as a double bar leg brace, we use the von Baeyer leather strap seat This was designed to replace the ischial seat of a Hessing type brace, an appliance that is difficult to build, uncomfortable for the patient in a sitting position, and often unsightly when worn by an obese patient

This construction transfers the body weight from the tuber ischii and the lower ramus of the ischium to the lateral upright longitudinal bar of a double-bar leg brace In this way, the construction differs in two important features from other "unweighting" braces First, a soft leather strap replaces the rigid and necessarily more bulky ischial seat of the Thomas ring or the Hessing brace On standing and walking the tuber ischii rests securely in the leather loop which naturally conforms to the shape of the body and causes no irritation at the perineum This is still more important for the sitting position which, with any of the rigid seat constructions, means considerable discomfort Moreover, the introduction of a leather strap as a weight transmitting seat simplifies the building of this type of brace

Second weight is suspended at the proximal ends of the external longitudinal bar at a level above the trochanter This calls for just one bar of great strength, while the other elements of the brace may be rather light The medial upright ends far below the perineum and the proximal semi circular band connecting *the two uprights may run far below the* gluteal fold The support of the body weight by the seat strap introduces a force which tends to keep the brace closer to the body, especially in the region of the trochanter the greater the weight placed on the seat This makes auxiliary forces, such as a pelvic band, superfluous

The leather strap seat lends itself to practically any type of brace construction one might select for the needs of the individual patient In its most primitive form the ischial strap seat brace may be built as a jointless brace with a patten with 2½ inches of clearance The ischial strap seat may be incorporated into any double bar leg brace with ankle joints and stirrups or sandals, provided there is a lock at the knee joint

Pressure of the strap on the adductor muscles can be avoided by adding a rectangular bar to the proximal end of the medial uprights One end of the leather strap is riveted to its horizontal arm

After the patient has worn the brace for some time, it is possible to trim the trochan-

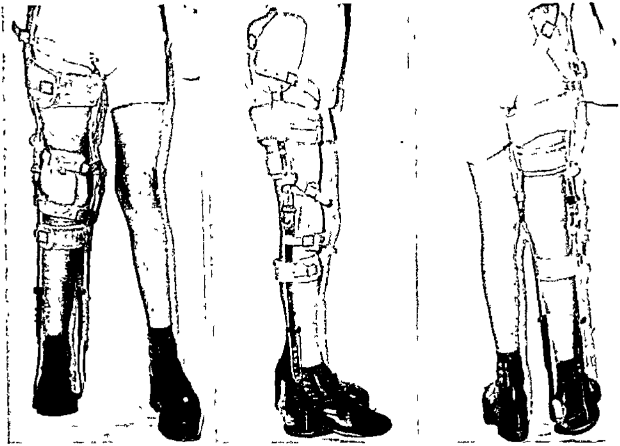


FIG 87. Ischial strap seat brace with ring knee lock and "Patten." Note heel strap to prevent weight-bearing on foot, and compensatory lift on left shoe.

teric pad as much as two inches without losing its unweighting effect. Where skilled labor is available and the expense is of minor importance, the brace may be built with a trochanteric lock joint. For this purpose, a unilateral double lock was designed by W. Tosberg, which is a modification of the O. I. knee lock joint. The small lever which operates the knee lock simultaneously operates the lock for the trochanteric joint. When the patient sits down, the hip and the knee joints may be flexed in a normal manner.

The development of the ischial strap seat brace into an appliance which is inexpensive, easy to manufacture—if necessary, within one day—and guarantees an efficient unweighting of the lower extremity without the usual discomfort to the patient, has widened the field for its use. The simplest form of the strap seat brace has proved extremely satisfactory in a number of cases of slipped femoral epiphysis, especially when applied in the so-called preslipping stage, and in Perthes' disease The more elaborate double-bar leg brace with the strap seat and lock joint has been successfully used in the treatment of patients with pathology of the hip joint, particularly malum coxae senilis Another group for which this brace may be recommended is the aged patient with non-union of a fracture of the neck of the femur.

The ischial strap seat brace is equally useful when the lesion requiring treatment is at the knee or foot section of the leg.

SPIRAL-BAR LEG BRACE

In outlining the general principles for orthopedic appliances for the lower extremities, we have stated that simple leg braces, which

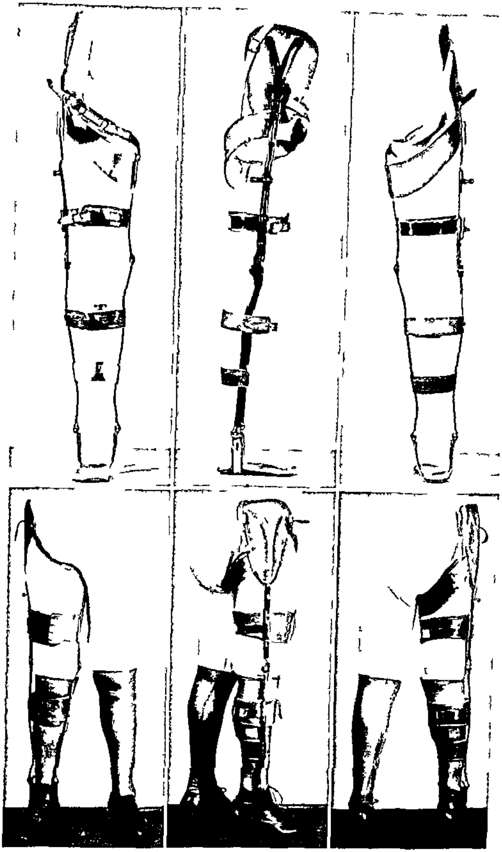


Fig 88 Modified ischial strap seat brace for partial unweighting of malum coxae senilis

are not built to a plaster of Paris model of the leg must be built as double bar braces, using two longitudinal bars There is, however, an exception to this rule The use of a single bar leg brace is possible and advisable for a considerable number of indications provided that such a single bar leg brace is constructed as a *spiral bar brace*

G Hohmann first suggested the use of such a brace in 1932 for the treatment of chronic productive osteoarthritis of the hip joint In 1933, he introduced a spiral bar foot brace for the support and correction of certain difficult deformities of the foot Since then he has developed and used the spiral bar leg brace for a considerable variety of deformities and dysfunctions of the lower extremities

Following Hohmann's recommendations we have built spiral bar leg braces for certain indications and we feel that this type of brace has its definite place among orthopedic appliances for the lower extremities

The construction of a spiral bar leg brace considers the correct static alignment of the entire extremity, with regard not only to the center axis of gravity and the plumb line but also to the element of torsion which plays an important role for painless functioning of the weight bearing joints in standing as well as in different phases of walking

To control the position of the joints of the foot and the knee, this brace must get a firm hold on the foot It then acts on the position of the foot in relation to the lower leg and in the case of a brace for the entire leg on the position of the knee within the alignment of the extremity Two main forces may be introduced with the spiral bar leg brace first, a lever action on the foot in the direction of pronation or supination as commonly used in the simple type of single bar lower leg brace for the correction of a club foot or a flat foot, second a rotatory force, correcting a malalignment to the longitudinal axis of the extremity in the direction of torsion

From a technical viewpoint, one may say that the spiral bar brace maintains a position between the generally inadequate single bar leg brace and the larger, heavier, more complicated double bar brace The arrangement of the single bar as a spiral encircling the column of the extremity, places approximately one-third of the bar on the internal and one third on the external aspect of the leg while the middle third runs across the anterior aspect of the lower leg or thigh in the case of a long brace Thus, this construction might be considered as eliminating a section of the two rigidly connected longitudinal bars of a double bar brace It gains sufficient stability by the ingenious design of its spiral like course It is thus perfectly adequate for the treatment of a considerable number of ailments of the lower extremities which require a brace for correction and for a moderate degree of fixation It is not to be applied however, for unweighting of the extremity for a higher degree of support or fixation or when immobilization is required

The spiral bar leg brace is a simple appliance Its construction permits considerable saving of labor and of material thereby reducing the cost of the appliance For the patient it has the advantage of being a very light brace generally worn in an ordinary shoe, which fulfills the requirement for the wearing of a foot plate It is less conspicuous than a double bar leg brace an advantage from the cosmetic point of view It is easily applied and facilitates later adjustments which can frequently be carried out with the aid of bending irons only

The spiral bar brace for the lower leg is indicated for a group of foot deformities which do not yield to treatment by an adequate foot brace but which on the other hand do not require a large appliance This brace is useful for the treatment of a rigid (spastic) pronated flat foot especially for recurrent attacks of pain and rigidity following closed or open operative procedures for correction of the deformity Moreover, it has its place in the treatment of osteoarthritic conditions of the ankle and subtalar joints Frequently, the spiral bar lower leg brace is adequate to maintain a paralytic pes equinovalgus in good

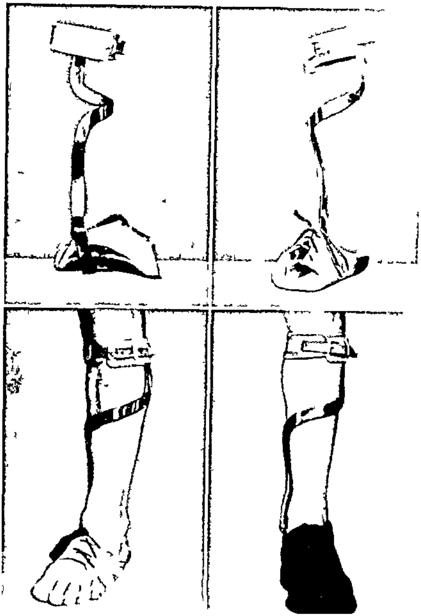


Fig 89 Spiral bar lower leg brace for painful rigid pes plano valgus

static alignment In the painful conditions which form the chief indication for this appliance the brace may be abandoned when the pain has subsided

The appliance consists of the foot brace the spiral bar and the calf band The foot brace and the spiral bar are joined with a milled ankle joint which may have a stop to limit dorsiflexion or plantar flexion as the case demands Although this brace can be made to a plaster of Paris model of the corrected foot only, its manufacture is facilitated by the use of a plaster model of the entire lower leg

For the foot plate 12 gauge Alcoa aluminum 2024 T4 or 16 gauge stainless steel is used high carbon tool steel 3/4 inch x 1/8 inch for the bar, sheet metal 1/16 inch x 1 inch for the calf band and a 5/16 inch steel rivet for the ankle joint

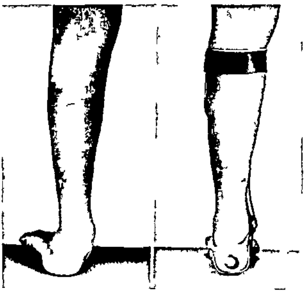


FIG 90 Spiral bar lower leg brace with ankle stop for paralytic valgus deformity

The contour of the foot plate is traced on the model The sole plate is made either with an outer flange at the heel and at the metatarsal region to prevent abduction and eversion of the foot or its shape may follow the outline of the original Whitman type foot brace The plate is cut from the metal and hammered on the lead following the usual procedure for a metal foot plate The foot is held in place by a leather sandal usually made of molding leather Where the requirements for fixation of the foot are not so strict the molding of the leather sandal may be eliminated and a simple leather lacing will be used The spiral bar follows the longitudinal axis of the lower leg from the ankle joint upward to the middle third At this level the bar crosses the tibial crest to the fibular side resuming the longitudinal course to its proximal end where it carries a calf band With the foot brace in the corrected position the spiral bar must follow the contour of the lower leg closely except for the crossing of the tibial crest where pressure must be avoided This may be accomplished by hammering the bar hollow over the site of the tibial crest As in every orthopedic appliance it is important to place the ankle joint in line with the axis of the natural joint When the fitting has been satisfactory the metal parts are nickel plated and the appliance is finished in the usual way by riveting the molded leather sandal or the leather lacing to the foot plate and by padding covering and lining the calf band which carries a strap and buckle

To apply the brace the foot is placed in the sandal which in itself affords the support and correction of an efficient foot brace When dealing with a rigid pronated flat foot the foot will still have a tendency to abduction and external rotation in relation to the lower leg The spiral bar therefore will deviate toward the medial side When placed in the proper position on the lower leg with the calf band closed with strap and buckle the spiral bar will exert a lever action on the foot and will correct the abduction pronation and outward rotation The brace requires very little space within the shoe enabling the patient to continue to wear the same shoe if desired alternating between the spiral bar brace and his regular foot plate The same construction principle may be applied for the pronation as well as the supination deformities The field for this brace may be enlarged by adding elastic forces substituting for lack of muscle power as in the case of a paralytic drop foot or by limiting motion at the ankle joint by means of the usual stops

This brace construction may also be used for the treatment of certain conditions of the knee joint Here it becomes a spiral bar long leg brace The indications for such an appliance are of course much more limited than for a lower leg brace The outstanding feature of the spiral bar long leg brace with regard to the knee joint is presented by the fact that it controls the static alignment of the entire extremity by its action on the foot It has a definite action on a varus or valgus deviation of the long axes of the tibia and femur at the knee joint while influencing at the same time the torsion of these two sections of the extremity commonly associated with a malalignment in the frontal plane While it can neither eliminate weight bearing nor afford a higher degree of fixation the spiral bar long

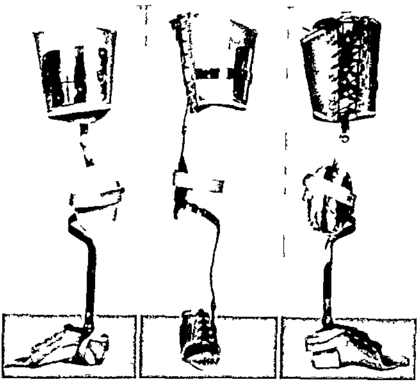


FIG 91 Spiral bar leg brace for arthrosis of knee joint

leg brace will improve the working conditions of the knee joint by means of its action on the *alignment of the extremity and by restricting* abnormal motions and eliminating shearing forces. This appliance is chiefly indicated for the treatment of arthritis or degenerative joint *disease and moderate degrees of varus or* valgus deformities with lateral instability following trauma. The brace is built according to the specifications described for the spiral bar lower leg brace. The lower leg bar runs from the ankle joint at the internal malleolus across the tibia to the external aspect of the lower leg. An oval external pressure pad of 18 gauge Alcoa aluminum 2024 T4 5½ inches x 3½ inches in size is added for greater stability by providing a firm hold on the lower leg below the head of the fibula. It is fastened to the proximal third of the lower leg by means of a strap instead of the calf band used in the lower leg brace. The lower leg bar is carried upward toward the knee joint where it is linked to the longitudinal external thigh bar by means of a simple knee joint permitting flexion and extension. The external longi*tudinal thigh bar runs in the direction of the* line connecting the trochanter with the external epicondyle of the femur usually ending at the distal end of the proximal third of the thigh. *To complete the spiral course of the* brace at the thigh a bar of the same material is riveted to the external longitudinal bar which runs transversely over the anterior aspect of the thigh to the *medial* side of the junction of the distal and the medial thirds. This anterior semi circular bar carries at its end a large pressure pad made of 18 gauge Alcoa aluminum 2024 T4 with an average size of 4½ inches x 5½ inches. The thigh is held in a cuff of 6 ounces of russet calf leather molded to the plaster of Paris model of the leg with the lacing on the external aspect of the thigh just posterior to the longitudinal bar. The fitting assembling and finishing of this brace are carried out in the usual manner. Special care must be taken to have the ankle and knee

joints of the brace at the correct sites to avoid the introduction of undesirable forces which would interfere with the aim of this appliance or at the very least cause discomfort to the patient

Provided the indications for this brace and its fitting are correct this appliance has its distinct merits particularly in cases which require the treatment of the foot as well as of the knee joint

SPLINTS AND BRACES FOR TREATMENT OF CONGENITAL DISLOCATION OF THE HIP

Large numbers of splints and braces have been designed for the treatment of congenital dislocations of the hip joint Many of these including the original large Hessing brace and later on the "small Hessing apparatus" are much too cumbersome for modern usage and have only historical interest At the present time a splint is applied at the earliest possible moment usually as soon as the diagnosis is established and this will gradually effect a reduction and maintain it The commonly used *Frejka pillow splint* and the *Freiberg splint* have proved their usefulness As they are available in various sizes it is unnecessary to discuss their manufacture

Most congenital dislocations of the hip discovered during the first years of life require reduction under anesthesia followed by immobilization in a plaster of Paris spica for a long period of time to encourage development of the acetabulum When the period of immobilization is terminated the cast is usually replaced by a removable orthopedic appliance to maintain reduction of the dislocation and permit the child greater activity

Celluloid or leather hip spicas or double hip spicas have been used for this purpose as have plaster of Paris or celluloid beds which include the legs or at least the thighs Their manufacture uses the molded leather or celluloid technique described for other orthopedic appliances and requires no repetition at this point

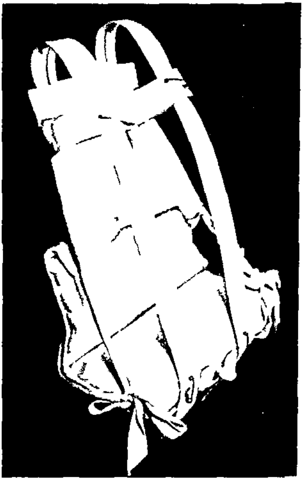


Fig 92 Frejka abduction pillow splint

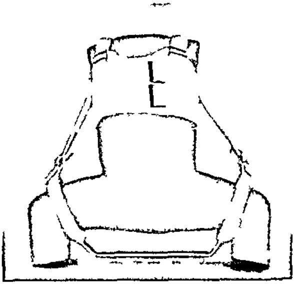


Fig 93 Freiberg splint for congenital dislocation of the hip (Courtesy Alfons R Glaubitz)

We prefer a rather simple device which is particularly useful in the after care of bilateral dislocation in small children This brace consists of a pelvic band cut from sheet metal (the gauge and width determined by the patient's size) with a cuff for each thigh The pelvic band is covered and lined with leather or sewn to a narrow corset or belt of coutil with a lacing at the anterior midline The cuff for the thigh consists of a rigid section of 16 gauge Alcoa aluminum 2024 T4 shaped to conform to the anterior aspect of the thigh covering the entire width and approximately two thirds of the length from the patella to the groin A leather cuff is cut to the pattern of the thigh encasing the entire thigh from the patella to the groin on the anterior aspect This is much shorter on the posterior aspect *in order to permit rectangular flexion of the* knee joint The leather cuff is fitted with eyelets and lacings close to the median edge of the sheet metal to which the leather is riveted The pelvic band and the thigh cuff are connected by means of a light bar of ½ inch by ⅓ inch high carbon tool steel on either side This brace is usually applied for a bilateral dislocation when the hip joints must remain immobilized with the thighs in 90° of flexion and 90° of abduction and the entire leg held in the frontal plane of the body with the exact degree of flexion adduction and rotation determined by the stability of the hip joints found at the time of reduction Fitting the brace to a patient in this so called frog position" the bars connecting the pelvic band with the thigh cuff form a right angle These bars are riveted to the external aspect of the pelvic band and to the top of the metal plates which form the rigid part of the thigh cuffs The bars will therefore lie in the frontal plane of the body with both arms of the right angle parallel to the longitudinal axes of the trunk and the thighs respectively

After the bars are nickel plated and the pelvic band and the thigh cuffs covered lined and fitted with lacing the brace is ready to replace the plaster of Paris double hip spica which has been bivalved for the brief period *necessary for the building of this appliance* The brace although small and light is quite adequate to maintain successful reduction of the hip joints especially in a smaller child One of its great assets is the simplicity with which changes of position of the legs necessary during the course of treatment are carried out When clinical and roentgenological examinations show that the roof of the acetabulum is beginning to form thus increasing the stability of the hip joints the degree of abduction and flexion is gradually diminished

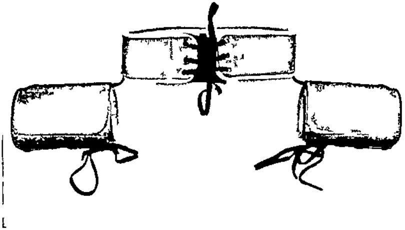


Fig 94 Simple appliance for congenital dislocation of the hip

Using two bending irons or bending pliers the angle formed by the bars connecting the pelvic band and the thigh cuff is easily ad justed so that joints are not necessary to the construction of this appliance

This brace is also useful for unilateral dis locations The normal leg must be held in a thigh cuff as in a bilateral case but the angle of the sound hip may be adjusted to a more comfortable position We consider this appli ance as the brace of choice in the after care of congenital dislocations of the hip for our youngest patients It is not intended as a walking brace as it does not afford sufficient stability for weight bearing nor can it guar antee fixation of the hip joints on walking If however at the end of treatment the hip joint has developed sufficient stability the use of this brace may be continued for addi tional safety while the patient is up and about

We should also like to mention an appliance *designed by Hohmann for the purpose of* stimulating the development of the acetab ulum in a case of reduced congenital dis location of the hip where the x ray picture at the end of prolonged treatment in plaster spicas shows an unsatisfactory development of the roof of the acetabulum Hohmann's brace consists of a pelvic band to which an abdominal corset may be attached A longi tudinal steel bar with a simple joint at the knee and at the trochanter permitting flexion and extension is placed on the external as pect of the leg from the pelvic band to the calf holding the thigh with two semi circular bands and cuffs and the lower leg with one at the distal end of the bar A pressure pad below the trochanter introduces a force which acts on the external aspect of the thigh press *ing the head of the femur as deep as possible* into the acetabulum This is accomplished by riveting the pressure pad to a spring which in turn is riveted to the inner surface of the longitudinal thigh bar above the knee The spring holds the pressure pad in the desired position while a long set screw through the proximal section of the thigh bar below the

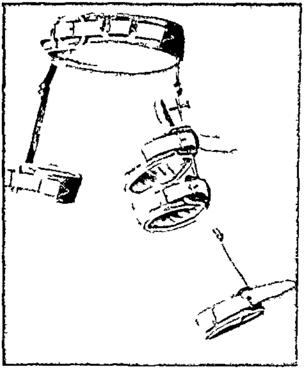


FIG 95 Brace after Hohmann for the after care of congenital dislocation of the hip

trochanteric hinge regulates the pressure Worn day and night the brace permits flexion and extension of the hip and the knee joint At the same time it stabilizes the position of the head deep in the acetabulum When the brace is first applied an abduction of 145° at the hip joint and a moderate internal rotation of the leg are maintained As soon as the x ray shows some development of the roof of the acetabulum the abduction is decreased and walking with the brace is permitted

The Short Hip Brace

The painful and disabling symptoms of the hip joint generally referred to as degenerative joint disease or *osteoarthritis may follow in* the wake of many pathological conditions Whether congenital originating in infancy or adolescence or resulting from a fracture of the hip they are largely disabling the patient in the older age group (malum coxae senilis) They have in common a dysfunction of the hip joint caused by an incongruence of the

articular surfaces of the head of the femur and the acetabulum

Hohmann designed a *short hip brace* in 1932 which has had a great measure of success in treating these conditions and which may be used in various modifications depending on the special requirements of the individual case

As a rule clinical examination in these cases reveals painful limitation of extension and abduction and fixed external rotation of the leg Hohmann s brace allows correction of the three elements of the deformity adduction flexion and external rotation Gaining a firm hold on the pelvis as well as on the thigh the appliance introduces the forces which abduct and internally rotate the leg by means of a lateral bar which runs from a trochanteric joint down the external aspect of the thigh crossing over the anterior aspect of the thigh well above the patella and ending in a pressure pad over the medial condyle of the femur A force for increased extension of the hip joint is introduced by means of a posterior elastic thigh strap or by a spring joint at the trochanter

This appliance permits a certain degree of *control of motion at the hip joint* Its therapeutic success is chiefly caused by abduction which changes by degrees the weight bearing

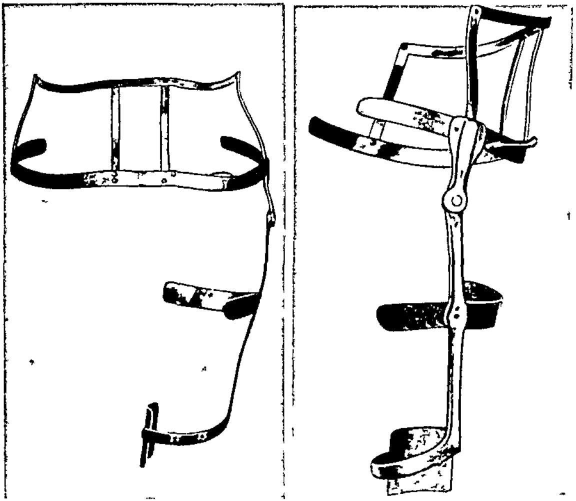


FIG 96 Spiral bar hip and hinged lower back brace with gluteal strap replaced on extreme right (page 125) by Lofstrand spring joint for extension of the hip

contact of the femoral head and the roof of the acetabulum from the most diseased to a less involved section.

Inasmuch as the more advanced stages of degenerative hip disease are frequently associated with flexion, adduction and external rotation contractures with marked muscular rigidity, but usually without adhesions or connective tissue shrinkage, this Hohmann short hip brace should not be applied without previous release of these contractures by manipulation under anesthesia. To give this appliance a certain amount of stability, we have found it advisable to construct the pelvic part of the brace as a hinged lower-back brace. This means that the short section of the single bar proximal to the trochanter joint is attached to the pelvic band of a hinged lower-back brace (see Chapter 3). Thus we increase the lever of the supra-trochanteric part of the appliance, stabilize the brace in all directions, and give the patient a support for his lumbosacral region and abdomen.

The short hip brace consists of a single long bar forged from ¾ inch x ½ inch high carbon tool steel. The bar carries a single joint for flexion and extension, located at the major trochanter. The short arm of the single bar runs from the trochanter joint to the pelvic band and is forged wider at the proximal end

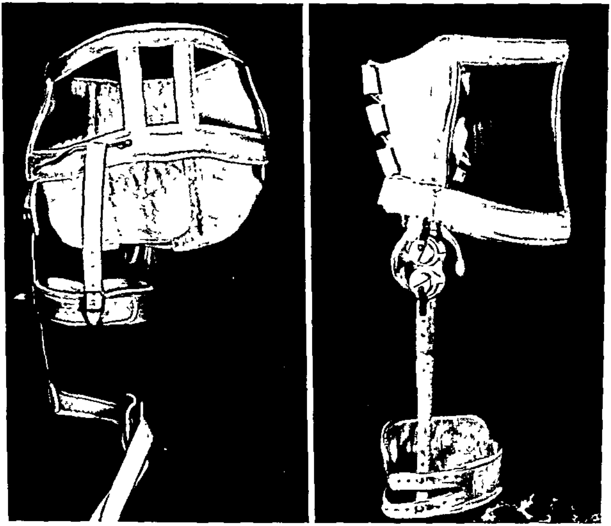


Fig. 96—Continued.

in order to make the necessary contact with the pelvic band The thigh bar runs from the trochanter joint downward following the course of a line connecting the tip of the major trochanter with the external epicondyle of the femur through the proximal two thirds of the thigh At the distal border of the middle third the bar turns almost at a right angle crossing the anterior aspect of the thigh about 2 inches above the patella and ending on the inner aspect of the thigh just above the internal femoral condyle The bar gains its hold on the inner aspect of the thigh by means of a pressure pad cut from 18 gauge Alcoa aluminum 2024 T4 in the shape of a square Its size depends on the individual patient It should be large enough to distribute pressure over a sufficient surface that is the medial aspect of almost the entire distal third of the thigh and yet not so large that it interferes with the function of the knee joint and the muscles controlling it The bar carries a semi-circular thigh band cut and hammered to shape from sheet metal This band encircles the thigh below the trochanter joint Its length is determined by the measure of half the circumference of the thigh at this level The level at which this transverse band is riveted to the longitudinal bar is determined by the fact that its posterior part must remain below the gluteal fold with the patient standing and its anterior part must not cause discomfort at the groin with the patient sitting This band is connected with the longitudinal bar by means of two rivets dividing the semi circular band in the ratio of 1 2 with one third lying anteriorly to the longitudinal bar and two thirds posteriorly It is practical to have the two parts not in a straight line but forming an angle at the connection with the longitudinal bar the anterior part forming a right angle with the long bar while the posterior part runs downward thus increasing the distance between the narrow thigh band and the pelvic band on the posterior aspect The band to which the short arm of the longitudinal bar is riveted corresponds to the pelvic band of the hinged lower back brace as described on pages 74 6 It differs insofar as it does not end at the level of the trochanter but continues toward the abdomen ending on both sides about an inch medially to the anterior superior spine On the outer aspect of the pelvic band from the trochanter bar and the anterior lateral upright to the posterior upright of the same side a strong wire or small rod is riveted and braced which forms an S or Z shape and serves as attachment for the posterior extension strap The rod is attached to the pelvic band near the posterior lateral upright at its upper border In its course toward the trochanteric end it runs upward for a length which corresponds to more than the width of the extension strap then bends sharply downward slanting toward the distal end of the pelvic band in the trochanteric region The exact bending of this rod is done at the time of the fitting in order to fulfill the purpose of the extension strap by tightening it when the patient is standing and walking and relaxing it by sliding it toward the trochanteric end of the rod through the clothing The steel skeleton of the short hip brace combined with the hinged lower back brace is readily understood from the illustrations After the first fitting the brace is finished in the usual manner by padding the pressure pads and the narrow thigh band by covering the hinged lower back brace and completing the appliance with an abdominal belt or corset front according to the requirements of the individual case The extension strap for the hip joint is sewn to the S or Z shaped rod and the corresponding buckle is sewn to the narrow thigh band at the correct location in the medial line of the posterior aspect of the thigh The brace is completed above the knee by sewing two straps and buckles to the proximal and distal ends of the inner thigh pressure pad

If the only joint of this brace at the greater trochanter is built as a spring joint or if a spring is added at this level for extension one can dispense with the extension strap in the back and its attachments

The efficacy of this brace depends upon the correct location of the trochanter joint which must permit flexion and extension of the hip joint without shifting the position of the brace on the body, and upon the effective introduction of the three forces which must bring the leg into abduction, extension, and internal rotation

Abduction of the thigh the most important element of correction, is controlled by the relationship of the external longitudinal bar to the hinged lower back brace The force is introduced chiefly by means of the pressure pad over the medial femoral condyle The amount of abduction is regulated by the use of bending irons Complete correction of external rotation is frequently impossible, but this deformity may be decreased to an almost neutral position by proper bending of the longitudinal bar, while the large inner thigh pressure pad over the internal femoral condyle transmits the corrective force The construction, manufacture and fitting of this orthopedic appliance do not present serious difficulties It is inconspicuous under conventional clothing, and whether it is made with an elastic or semi elastic front, it improves the posture and permits the patient complete comfort in a sitting position All desirable adjustments can be made by means of bending irons, by shortening the elastic strap, or by tightening the spring at the trochanter

SPLINTS AND BRACES FOR THE KNEE

Among the pathological conditions of the knee joint for which an orthopedic appliance is indicated, many do not require a major apparatus for the lower extremity, such as the Hessing type, the double bar, or even the spiral bar brace, described in the earlier parts of this chapter An elastic knee cap an ACE bandage, a strapping or a variety of so-called "short knee braces" are frequently used Many of these, however, cannot fulfill the requirements of support and partial immobilization of the knee joint while at the same time, permitting normal circulation to the lower leg

Posterior Flexible Knee Splint

The simplest appliance which meets these conditions is the posterior flexible knee splint, which, if properly applied, affords not only a considerable degree of immobilization of the knee joint, but also protects the neurovascular structures in the popliteal region Consequently, a great deal of compression can be used to reduce swelling of the knee joint where indicated, without interfering with circulation below the knee

This appliance consists of a large felt pad reinforced with three steel springs or whale bones

The basic material is 5/16 inch fine quality white felt cut to a pattern 12 inches long and 4 inches wide at the "waist,' which corresponds to the knee joint This widens at the top to 5½ inches and at the calf end to 4¼ inches Three springs of blue spring steel, 3/8 inch wide, are cut to a length of 9 inches with the ends rounded and smoothed A piece of white or gray coutil is cut to twice the width of the felt and to the length of the splint, adding two inches at each end for the seam The coutil is sewn on the felt in a double layer The springs are inserted and the free ends are turned back and seamed down, thereby protecting the ends of the steel springs with four layers of coutil

The splint is kept in stock in two or three sizes for immediate use in emergencies Placed on the posterior aspect of the leg in the popliteal space and held in place by a 3- or 4 inch ACE bandage, it gives excellent support to a painful knee joint The elasticity of the spring steel permits a sufficient degree of flexion and extension to enable the patient to walk and sit comfortably The whalebones will not, however, bend over the edge and this eliminates lateral movement in the direction of abduction and adduction of the lower leg as well as rotation The felt pad is worn directly on the skin to which it readily adheres It does not shift its position without requiring undue constriction by turns of the ACE bandage The posterior flexible knee splint may be used to advantage whenever

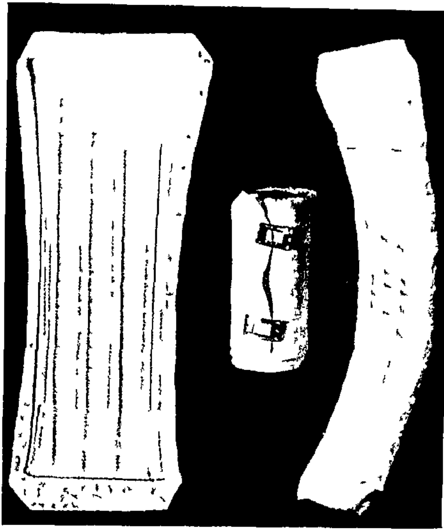


FIG 97 Posterior flexible knee splint and ACE bandage

fixation and moderate immobilization of a knee joint are desirable particularly where lateral strain must be avoided This is the case in injuries to the lateral ligaments and to the semilunar cartilages following surgery for removal of a torn semilunar cartilage or preliminary to the manufacture of a leather strip knee brace

The use of this splint in combination with an ACE bandage does not produce impairment of circulation which is frequently associated with application of an ACE bandage a circular strapping or an elastic knee cap

This appliance has also proved most valuable as an emergency splint for the many knee injuries resulting from mishaps in sports or traffic and involving the hemophilia patient It is also indicated postoperatively for almost all surgery on the knee joint not followed by application of a cast

For the more specific requirements of hemophilia patients the so called hemophilia emergency splint" was designed to afford rigid immobilization of the knee joint at any desired angle of flexion This splint which can also be used for the elbow is applied with one or two ACE bandages and should be kept in stock in a few sizes

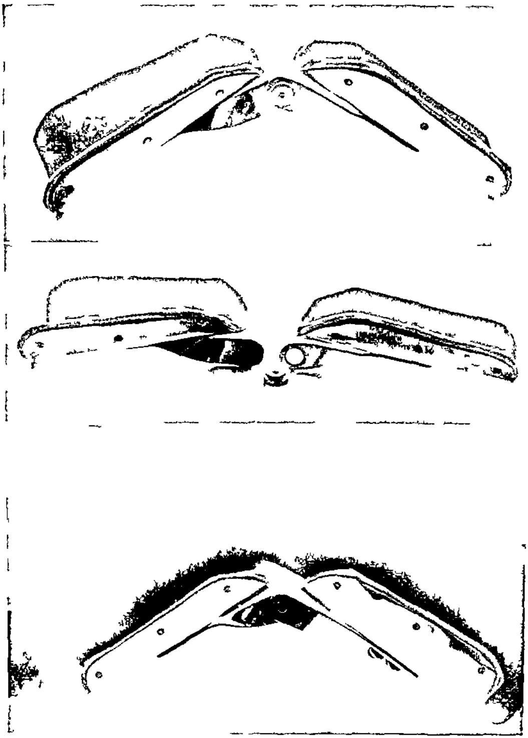


Fig 98 Hemophilia emergency knee splint

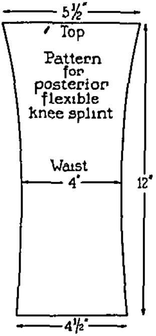


FIG 99 Pattern for flexible kne splint

Leather-Strip Knee Brace

The leather-strip knee brace was designed by J Fuchs for the treatment of a painful knee joint caused by various pathological conditions, such as chronic synovitis, degenerative joint disease, recurrent hydrops and the many sequelae of trauma This appliance solves the difficult problem of supporting the painful knee joint while, at the same time, eliminating undue strain, excessive motion and faulty alignment of the articular surfaces, *without interfering with the desirable degree* of function or with the circulation

In 1927, Fuchs published a text book offering a detailed discussion of the use of the leather strip technique While he described his technique for almost every indication requiring a brace in orthopedics, we have limited its use to conditions of the knee, ankle and foot Results obtained in several hundred cases, especially in the treatment of osteoarthritis of the knee joint and similar conditions where a leather strip knee brace was indicated, have been so gratifying that we regard the appliance as one of choice for the prolonged ambulatory treatment of these cases A considerable number of orthopedic surgeons using this construction have reported similar good results

The leather strip technique is quite exacting and requires a skilled leather worker, a good deal of practice and plenty of time Given these conditions, together with meticulous attention to the specifications outlined by Fuchs, the end product will be a superior orthopedic appliance that guarantees a degree of satisfaction to the patient, rarely encountered with other types of braces For this reason we feel that a detailed description of the leather-strip knee brace is well justified

A typical leather strip knee brace consists of five or six single transverse strips of soft leather covering the region of the knee joint from approximately 5 inches above to 5 inches below the patella To hold them in position these cross strips are sewed to two longitudinal strips fitted with eyelets for lacing Calf leather is used A bracemaker experienced in the manufacture of the leather strip knee brace must frequently search the market for faultless skins These have a characteristic feel Their elasticity frequently determines the efficacy of the brace A light color which does not fade or stain is desirable

The bracemaker cuts the five or six transverse strips and the two longitudinal eyelet strips to a standard pattern that is varied according to the size of the patient's leg The patient lies down with the knee slightly *flexed and the leather is stretched and molded* on the skin The first strip is applied to the center of the knee, using surgical clamps or hemostats to assure tight fitting When the first strip is in place, the knee is flexed and extended in order to find the correct location of the strips in relation to the axis of the knee joint Next, the two proximal and two distal strips are applied in a similar manner, with the strips overlapping each other like shingles The position of the longitudinal strips with the eyelets depends upon the purpose of the brace and varies accordingly In some cases limitation of movement and compression of

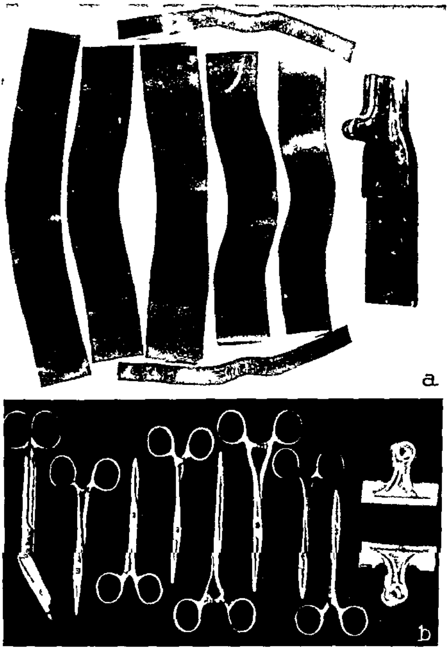
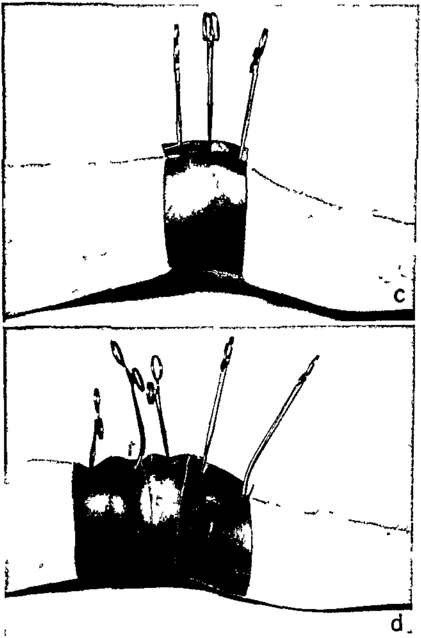


Fig 100 Manufacture of a leather strip knee brace (a) The leather strips and the molding block (b) clamps and clips (c) center strip in position (d) three strips in position (e) five strips in position (f) the longitudinal strips are attached (g) the appliance ready for sewing (h) the finished appliance on the leg (i and k) The leather strip knee brace may be reinforced by three steel whalebones in the back, permitting flexion and extension of the knee joint while eliminating lateral movements



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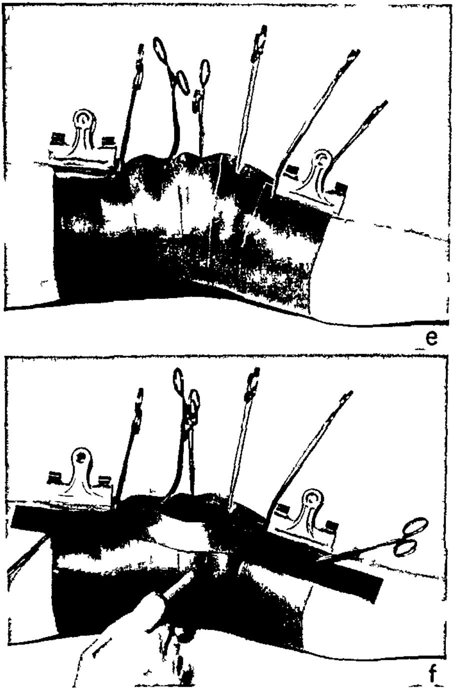

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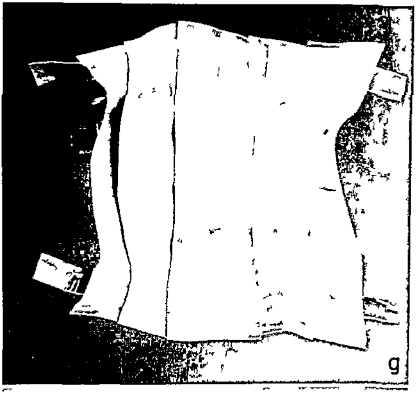

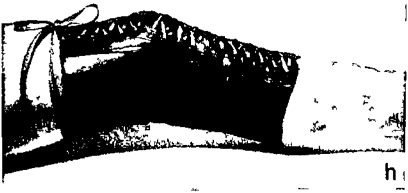

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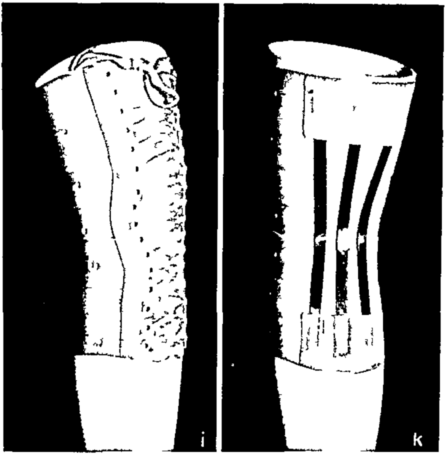


Fig 100—Continued

an effusion are desired, while in others the aim is to produce hyperemia of the knee joint

The strips may be applied so that a tendency toward extension of the knee joint results or, in other cases, to obtain a tendency toward flexion or limitation of a recurvatum When all the leather strips are properly molded and fitted, their relative position is marked off with a pencil and the two longitudinal strips for the lacing may be held in place by rubber cement The clamps are removed and the appliance is ready to be sewn Next, the ends of the transverse strips are trimmed to avoid too much overlapping although sufficient material is retained to cover the skin beneath the lacing in case of an effusion into the knee joint Finally, the holes for the eyelets are punched The eyelets are inserted and a silk lacing of matching color is added

The brace permits control of an effusion, as well as an increase of synovial fluid through the production of hyperemia As it does not interfere with the proper play of the quadriceps, it causes little if any muscular atrophy Talcum powder is abundantly applied to the skin before the brace is fitted to the patient to facilitate easy gliding of the strips on movement of the knee joint

Sometimes a higher degree of immobilization is necessary as, for example, when an osteoarthritic joint becomes acutely painful following a sprain or locking of the knee joint. For this purpose we have added a very simple fixation device by fitting the proximal and the distal strips with three small pockets at the back which permit the insertion of three whalebones in the popliteal space These the patient can insert or remove whenever necessary When in place, they allow suffi

cient flexion and extension to render walking and sitting comfortable They do not however bend over the edge so that there is no lateral motion or strain on the joint

The brace must be fitted by or under the supervision of the orthopedic surgeon as the various indications for this appliance necessitate individual adjustments Once the brace is properly fitted it requires practically no care although it may be ironed if necessary The patient is instructed to apply the brace in the morning while still in bed and he may wear it throughout the day It causes neither chafing nor discomfort provided enough talcum is used to insure proper gliding of the strips

While the leather strip technique is chiefly used in the treatment of the conditions of the knee joint mentioned above the same technique lends itself well for certain conditions of the ankle and foot as shown in Figure 101

Hewitt Type Elastic Knee Brace

Searching for an orthopedic appliance for the knee joint that would be as effective as the leather strip knee brace but much easier to manufacture we adopted a front lacing long elastic knee brace with posterior steel bars and hinge and have been using it for the past twenty years

This brace was designed in 1939 by E R Hewitt engineer and inventor after long experimentation in a search for adequate support for his own painful knee joint The brace was therefore introduced as the Hewitt type elastic knee brace"

The appliance is made of heavy woven elastic such as is commonly used for a knee cap It is woven to the patient s measurements or cut from stock material It is reinforced by solid leather lace stays in front and two spring steel bars with a piano hinge in the back The leather eyelet strips are cut to a pattern which curves around the patella The lacing permits separate adjustment of the elastic material to the thigh and lower leg sections of the knee In the region of the knee the brace is laced *in the fashion of a tobacco pouch* avoiding pressure on the patella while at the same

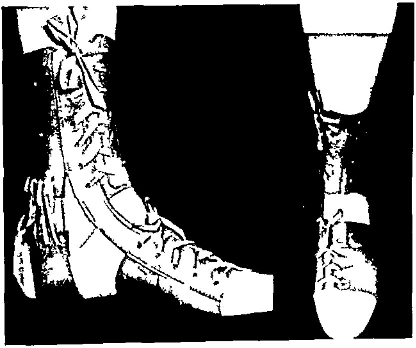


Fig 101 Leather strip brace for the ankle and foot

time, exerting a concentric pull which adds considerably to the support offered by this elastic material in every position of the knee joint. Posteriorly, two large leather pockets are sewn on to the thigh and lower leg section of the elastic material. Two pieces of spring steel 1½ inches by 3/16 inch are articulated by means of a solid bronze hinge, milled in ten sections. The steel bar for the thigh averages 5¼ inches in length, and the bar for the lower leg is 4½ inches long. The leather pockets must be approximately ½ inch longer in order to permit flexion without undue pressure of the metal hinge on the posterior aspect of the knee. When the steel bars are inserted into the pockets, the hinge lies in the center of the popliteal space. This hinge permits flexion and extension of the knee joint but prohibits lateral motion in order to avoid undesirable strain on the lateral ligaments and internal structures of the knee joint.

The degree of flexion allowed by the brace is established by the relationship between the length of the arms of the posterior hinge and the leather pockets. The longer the arms, the less flexion is permitted. After the brace has been worn for a short while, it is advisable to rivet the proximal arm of the hinge to the leather pocket. This will prevent a tendency of the brace to ride down. In addition loops may be attached to the proximal end of the brace so that it may be held up by the garters of a girdle when the appliance is worn by women with heavy or cone shaped thighs.

While the original design of the Hewitt type elastic knee brace has been continuously in use, there have been a few modifications. The original brace uses unlined separate leather tongues above and below the knee leaving the patella uncovered. For hemophilia patients, the appliance has been fitted with a one piece foam rubber padded leather tongue for greater protection of the knee. In some of these cases, flexion of the knee may be further restricted by using a solid spring steel bar in back in place of the piano hinge.

For patients with temporarily weak quadriceps and lack of stability from incomplete extension, an extension spring added to the posterior hinge has been very beneficial. Also in cases of traumatic or recurrent dislocation of the patella, the Hewitt type elastic knee brace

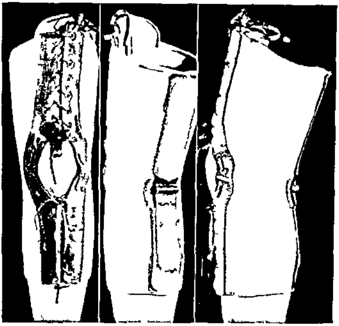


Fig. 102. Hewitt type elastic knee brace.

has been successfully used with a special pressure pad inserted at a point where it would prevent lateral movements of the patella

DROP FOOT BRACES

Treatment of a pes equinus or drop foot frequently calls for the use of an orthopedic appliance Brace construction will be influenced by the type of deformity to be treated as well as by the purpose of the appliance As to the former we must classify the conditions as fixed or flexible and according to their origin as paralytic spastic traumatic arthritic and so on Concerning the latter, the appliances may be divided into night braces and walking appliances

care following surgery such as for lengthening of the tendo Achillis

Appliances designed to correct a deformity especially a fixed or rigid one must permit the application of corrective forces The three point system must operate here as always In the case of an *equinus deformity one corrective* force must act on the ball of the foot one on the posterior aspect of the lower leg and the opposing force must function dorsally at the instep

While the introduction of the three point system is the main object of a corrective drop foot night brace an appliance of this type should be built along simple lines and in such a way that it can be applied easily and fastened with one or two straps Obviously

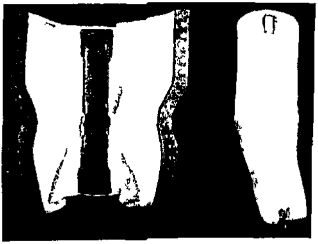


FIG 103 Hewitt type elastic knee brace with one piece foam rubber padded tongue

Drop Foot Night Braces

A drop foot night brace is used as a matter of prophylaxis so that an equinus deformity will not develop under prolonged bed rest or in cases of muscular imbalance caused by trauma or neurological disease Because these preventive drop foot night splints do not have to introduce corrective forces their construction is very simple Plaster of Paris splints felt covered aluminum splints or simple celluloid drop foot night splints may be used The celluloid brace is used for after

an ambulatory adult patient with a spastic hemiplegia would hardly wear a drop foot night brace if it were difficult to apply unless he had adequate nursing care

In constructing a drop foot night brace that fulfills the necessary requirements it is practical to introduce the forces on the ball of the foot and at the posterior aspect of the lower leg by means of a "half shell" made of celluloid or molding leather to a plaster of Paris model The foot section corresponds to the distal half of a celluloid foot plate The lower leg is held in the middle third just be

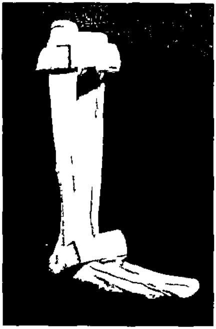


FIG 104 Simple celluloid drop foot night splint to maintain correction

low the bulk of the calf muscles by a half round section about 5 inches wide, which covers the posterior half of the circumference When the celluloid or leather parts are hardened on the model they are fitted with a transverse, semi circular band of sheet metal at the calf and a similar band or light bar under the ball of the foot Two longitudinal bars are forged from ⅝ inch round edge high carbon tool steel to connect the semi circular band at the lower leg and the transverse bar under the ball of the foot on either side

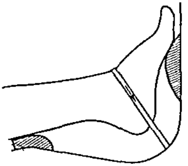


FIG 105 Diagram Correction of rigid pes equinus (From Hans von Baeyer *Grundlagen der orthopadischen Mechanik* Berlin 1935 courtesy Julius Springer)

These longitudinal bars follow a straight course on the external and internal aspects of the lower leg to about 3 inches above the malleoli from where they are traced posteriorly towards the heel, encircling the malleoli and bending almost at right angles to the internal and external aspects of the foot, ending at the same level in a line with the metatarsal heads These two longitudinal bars which are required to introduce the three forces operating on the foot, are articulated to the sole plate with a simple joint This permits motion of the sole plate around a transverse axis so that it can follow the sole of the foot when the position of the ankle joint is changed by decreasing the degree of equinus The proximal end of the two longitudinal bars may be rigidly connected with the lower leg section of the brace by rivets, or a joint may be used permitting some motion for this section The latter is preferable in many cases In every instance a posterior semi circular bar must be added as a third transverse structure to stabilize the position of the longitudinal bars This bar must be wide enough to avoid pressure on the tendo Achillis A well padded leather strap over the instep of the foot which is attached to a stud on the external and internal longitudinal bar at the point of the angle toward the heel completes the simplest form of this appliance This is finished in the usual way by nickel plating the metal parts or by covering them with leather and by lining the half shells

In this brace, the leg finds its right place almost automatically because of the accurate form of the sole plate and the lower leg section and the swinging motion which these sections have at their connection with the longitudinal bars The opposing force of the three point system is now added by passing the strap over the instep using as much pressure as the patient can tolerate without discomfort or interference with circulation No additional straps or lacings are required to hold the foot in position This means that the

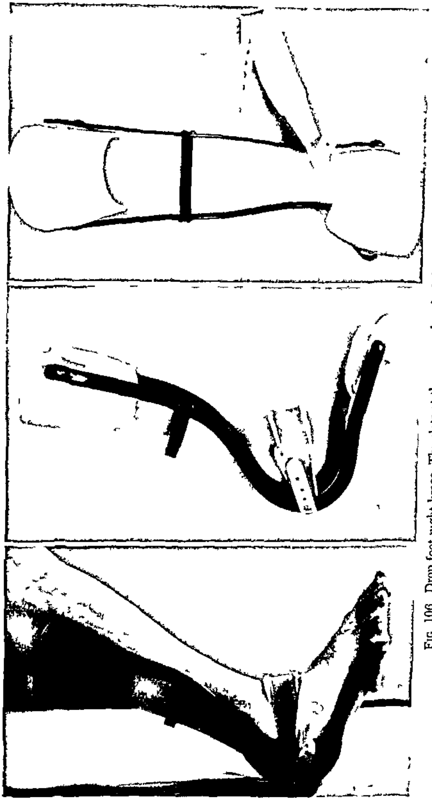


Fig 106 Drop foot night brace The slots at the proximal end of the steel bars permit the calf to follow the downward movement of the heel

patient has only one strap to fasten when applying the brace

Drop Foot Walking Brace

A drop foot walking splint or brace is chiefly indicated in neurological conditions such as the paralytic and the spastic drop foot The paralytic drop foot is usually found in a leg requiring a more extensive brace that incorporates ankle stops elastic straps or spring joints at the ankle for dorsiflexion of the foot The spastic drop foot however benefits greatly from a simple posterior steel spring splint Preliminary surgery for lengthening of the tendo Achillis may be necessary in these cases

FIG 107 Simple drop foot brace (Courtesy Alfons R Glaubitz)

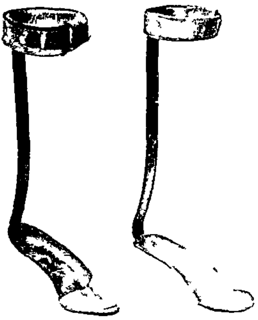


FIG 108 Posterior drop foot splint with calf band attached to fiberglass foot plate on the left and leather-covered metal plate on the right

FIG 109 Von Baeyers drop foot walking appliance The "spur" and the two elastic straps are attached to the shoe upright and calf band may be used with several shoes

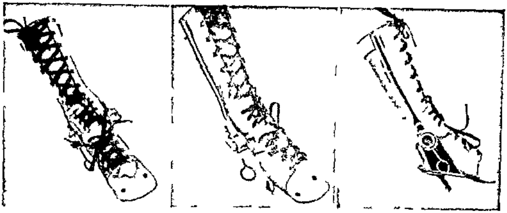


Fig 110 Hemophilic lower leg brace for correction of residual equinus deformity with Lofstrand spring joints at the ankle A separate ankle cuff is used to hold the heel to *the foot plate of the sandal Note the small key inserted into the Lofstrand spring joint* to eliminate the spring action when the brace is put on After removal of this key spring action forces the foot gently into more dorsiflexion

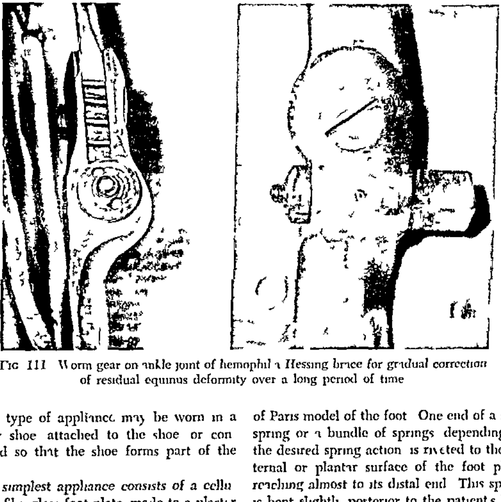


Fig 111 Worm gear on ankle joint of hemophilia *Hessing brace for gradual correction* of residual equinus deformity over a long period of time

This type of appliance may be worn in a regular shoe attached to the shoe or constructed so that the shoe forms part of the brace

The *simplest appliance consists of* a celluloid or fiberglass foot plate made to a plaster of Paris model of the foot One end of a steel spring or a bundle of springs depending on the desired spring action is riveted to the external or plantar surface of the foot plate reaching almost to its distal end This spring is bent slightly posterior to the patient s heel

to form a right angle with the longer arm extending upward on the posterior aspect of the lower leg to the mid calf The upper end of the spring is slotted to permit attachment of a moderately padded, semi circular calf band with straps and buckle The slots in the upper end of the spring (suggested by Hohmann) eliminate friction between the brace and the leg on movements of the foot This very light and easily applied brace is our preferred drop foot splint for most elderly patients with spastic hemiplegia

While this walking brace may be worn in the patient s regular shoe, there is also a definite indication for the attachment of the same type of posterior spring steel splint to the shoe Here, the foot end of the spring steel splint is connected to a steel plate which is riveted to the shank of the shoe where it must reach down to the metatarsal heads Because this splint is placed outside the counter of the shoe a leather loop or small strap and buckle are needed at the upper end of the counter to hold the splint and increase its dorsiflecting efficiency

In passing it should be stated that a compensatory equinus deformity in a short leg should not be corrected Where it causes pain however it should be supported by a suitable foot plate or by the *forefoot equinus shoe*

Many variations or modifications of the drop foot splint and brace described above are practicable We should like to mention a combination of a corrective drop foot night brace with a walking appliance For correction of residual equinus deformities from hemorrhages into the calf muscles of hemophiliac patients we have used a Hessing type lower leg brace with ankle spring joints for dorsiflexion of the foot With this construction a separate ankle cuff is needed to hold the heel to the foot plate of the sandal

EXTENSION BRACES FOR EXCESSIVE SHORTENING

The orthopedic surgeon is often confronted with the problem of compensation for a shorter leg Frequently, a patient is unaware of moderate inequality in the length of his legs This is discovered almost accidentally during examination of a patient who may complain of lower back pain or who seeks advice because one hip is "sticking out" A pelvic obliquity is found which may be caused by a difference in length of the legs The influence of one shorter leg on the position of the pelvis and the spine, and consequently on the static and dynamic conditions of the entire body, has already been discussed in Chapter 3 (section on von Baeyer's "Closed Chain") This is not the place to enumerate all the causes of shortening of one leg, or the various indications for treatment We can assume that we are dealing with a fixed difference in leg lengths and that the shortening of one leg is the end result of injury or disease, regardless of whether this has required treatment by orthopedic surgery The question is whether we have to compensate for shortening of the leg and if so, how this is to be accomplished

Nature normally compensates for shortening up to one inch, by lowering the pelvis on the short side, and beyond one inch by developing an equinus position of the foot which over a long period of time, gradually leads to tightening of the tendo Achillis The pelvic obliquity, as well as a moderate equinus position of the foot, may compensate for the shorter leg without the patient s knowledge and without visible influence on standing and walking

Despite nature's course, we feel that an orthopedic appliance should be used to compensate for shortening of an inch or more as soon as it is discovered in order to prevent the undesirable effects which sooner or later lead to symptoms, such as metatarsalgia, limitation of dorsiflexion at the ankle, myogeloses in the calf muscles, static pain in the entire extremity, a sacroiliac syndrome or a postural scoliosis

Treatment of a moderate degree of shortening presents no difficulty We can raise the

heel of one shoe and lower that of the other or we can make a foot plate to compensate for all or part of the shortening and at the same time accomplish proper distribution of weight within the foot Where shortening is more extensive correction of the equinus deformity by lengthening the tendo Achillis is *certainly contra indicated The equinus position* of the foot is a necessary aid in compensating for the shortening of the leg it will generally suffice to support the foot in the necessary equinus position by means of a foot plate made to a plaster of Paris model of the foot carefully molded to the sole at the heel in order to support the body weight primarily at the heel

If however shortening of one leg is excessive and ranges between two and eight or even ten inches we have before us a major problem in brace construction unless the physician the bracemaker and the patient resign themselves to the unsightliness of an old fashioned shoe with an enormous cork sole

In dealing with such excessive shortening of a leg brace construction has to consider the following tasks

1 Compensation for the extensive shortening

2 *Concealment of the shortening in an appliance* which is good looking and acceptable *to the patient from a cosmetic point of view*

3 Stability of the leg

4 Painless weight bearing with the foot in the desired position

5 Sturdiness of the brace so that it does not require great care or frequent repairs

6 A design that enables the patient to wear stock shoes

These requirements may not always be met because of the amount of shortening and the deformity of the foot which may cause or result from the shortening The task is sometimes easier if the shortening is connected with atrophy in a paralyzed leg requiring the use of a leg brace We build such a brace according to the general principles for the construction of leg braces with the foot part constructed as a sandal which holds the foot firmly in the desired degree of equinus position using cork and felt with steel reinforcements until the contour of the normal foot is reached thereby permitting the patient to *wear a pair of stock shoes*

If a leg brace is not required the type of appliance *will vary according to the need of* the individual case

In addition to the lower leg *brace for a* short leg and the outside shoe extensions which are still widely used a number of firms here and abroad have recently specialized in *inside shoe extensions* These devices are made of molding leather to a plaster of Paris model with the foot held in equinus and supported on a compensating extension made of light wood rubber cork felt or a combination of these materials As a rule these appliances are laced in front like a shoe and worn inside a stock shoe If made with proper consideration of the requirements outlined above emphasizing weight bearing comfort and stability these inside shoe extensions give satisfactory results provided first that shortening is not too extensive and second that the form and dimension of the foot and lower leg may be concealed in a molded leather appliance *without creating an unfortunate appearance*

The inner shoe extension cannot be used however *in the presence of marked deformity* furthermore the stability of this appliance is too limited to control the position of an unsteady foot

For a patient with excessive shortening of a leg and a weak foot which is otherwise well formed we recommend an extension brace similar to the type of artificial leg used for a Pirogoff amputation For this appliance a plaster of Paris model is made of the lower leg and the foot with the patient standing and the ankle joint held in the highest degree of plantar flexion obtainable Its construction

makes it an anterior brace with the opening and lacing posteriorly, that is, at the calf An artificial foot with toe action corresponding in size to the patient's normal foot is built from light wood to the height of the required extension The height of the heel and the position of the plaster model on the wooden foot, as determined by the plumb line, is then considered before conforming the artificial wooden extension to the shape of the sole of the plaster model To avoid transmitting too much body weight to the metatarsus the weight bearing is brought to the heel on the wood extension by slightly flattening the heel of the plaster model

The steel work is now fitted over the wooden extension and plaster model The two longitudinal bars are made as a stirrup and are connected at the proximal end by an anterior semi circular steel band reinforcing the molded leather at the level of the tuberosity of the tibia while at the foot the stirrup widens and is screwed from beneath to the wooden extension

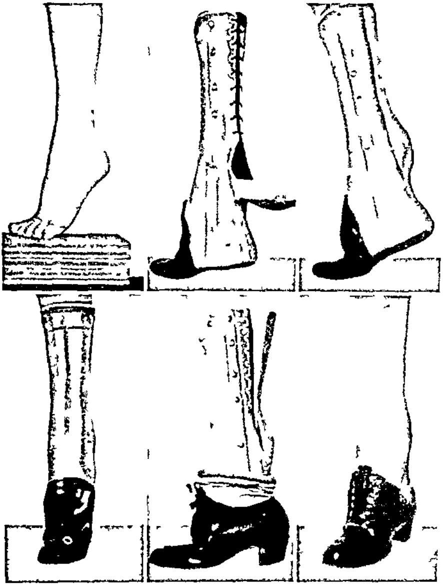


FIG 112 Lower leg brace for excessive shortening following osteomyelitis of femur

A paper pattern is then cut for the molding leather This will cover the plaster of Paris model of the lower leg and foot and simultaneously include the artificial foot leaving only the toes uncovered The leather having been soaked in the usual manner is drawn over the anterior and lateral aspects of the model The steel skeleton which already connects the artificial foot with the leg part of the brace is well embedded in the molding leather with the molding tool When hardened to shape the molding leather is taken off the model and trimmed almost to the posterior *edge of the upright bars and anteriorly over* the instep of the foot

In assembling the brace care must be taken to preserve the proper angle between the longitudinal bars and the foot Additional ¼ inch steel rods riveted through the longitudinal bars and the wooden foot will give this extension brace the proper stability

The appliance is now ready for the first fitting The patient slips into the brace from the back with the dorsum of the foot resting against the anterior wall of the molding leather The brace is held to the leg by means of a few straps with buckles The patient must test the brace standing and walking

Construction of this appliance is a fairly simple procedure until we are confronted with the difficulty of securing sufficient space in the shoe for the forefoot and the toes This frequently requires a special shoe the uppers *of which are cut to the individual measure*ments in order to provide a pleasing cosmetic appearance without undue pressure on the toes and to avoid the unsightliness of a bulge at the distal end of the foot as well as an unsightly spreading of the lace stays This problem is mainly financial If the patient can afford special shoes we can guarantee an attractive appearance as well as comfort for the toes For Figure 112 on the preceding page we used a cheap stock shoe While this patient with a 5¼ inch shortening obtained perfect comfort and all the other advantages of this type of extension brace the cosmetic appearance of the appliance was satisfactory only from the front while the side view showed how the shoe was disfigured to provide space for the toes A molded shoe or so called "space shoe" is much more satisfactory for these cases Nevertheless the entire appearance of the patient was much better with this brace than it had been with the outside shoe extension previously worn

If the *fitting proves satisfactory* the entire brace is covered with soft leather Eyelets are added for lacing at the calf down to the heel and this lacing is covered with a flap of leather which is held in place by the stocking Finally the fit of the appliance is checked by x ray in order to determine the proper position of the foot and especially the heel in the appliance

This type of extension brace for excessive *shortening fulfills most of the requirements* listed above It insures proper weight bearing without discomfort to the patient and good stability for a weak foot It also eliminates weak points requiring frequent repairs Its use is therefore economical and its cosmetic appearance ranges from good to excellent depending on the type of shoe used Naturally such an extension brace for excessive shortening will always represent a compromise and is therefore the least of several evils One of the obstacles to a good cosmetic appearance is the contour of the heel which is frequently hard to conceal within the appliance If an adult patient has worn a brace of this type over a long period of time with satisfactory results but is very anxious to have the appearance *improved one might consider at least* theoretically plastic surgery of the heel to remove part of the posterior prominence of the os calcis maintaining however the action of the calf muscles by adjusting the length of the tendo Achillis

CLUB FOOT NIGHT BRACES

Whether congenital or acquired as the result of infantile paralysis trauma or other mis

fortunes, a club foot presents a difficult problem to the surgeon. No matter which of the many closed or open methods of correction are used to overcome the deformity, the main difficulty in the majority of cases is the obstinate tendency of the club foot to recur. Even when treated at the earliest possible moment or after an apparently perfect surgical result, the foot must be maintained in a corrected or rather over corrected position for many years. For this purpose, the application of a corrective appliance during the night, the so called club foot night brace, is indispensable. In cases of minor or moderate deformity, a club foot night brace may be used as a primary means of correction, as well as for the purpose of maintaining the achieved correction. The construction of an effective appliance for this purpose is not an easy task. In the case of a new born infant or a very small child, it is difficult to gain sufficient hold on the small and delicate extremity. Furthermore a club foot presents a complicated deformity with up to five component elements, each of which requires the action of a three point system in order to obtain an efficient correction. These difficulties, together with the great variety of deformities which come under the heading of a club foot, explain the large number of brace constructions reported in the literature throughout the centuries as well as the many varieties of constructions which are on the market or recommended by orthopedic surgeons. Although there are many efficient constructions, we cannot describe them all. So we shall again limit our discussions to the general principles involved, giving only a few examples of appliances which we believe to have definite advantages.

In a complete club foot (the congenital type), a brace construction has to introduce a system of forces to counteract the following components:

1. Adduction of the heel and forefoot: pes adductus.
2. Exaggeration of the longitudinal arch and the dorsal prominence of the tarsal region: pes excavatus.
3. Plantar flexion of the foot: pes equinus.
4. Supination of the entire foot.
5. Internal rotation of the tibia.

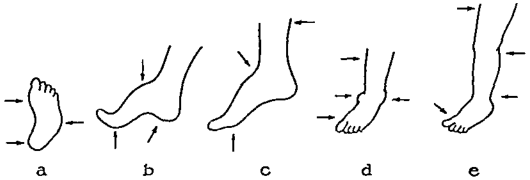


FIG. 113. The five components of a club foot. (Redrawn from Hans von Baeyer, *Grundlagen der orthopadischen Mechanik*, Berlin 1935, courtesy Julius Springer.)

Correction of each of these components requires, as stated above, the action of three forces. While these are easily applied for the correction of the equinus deformity, correction of the cavus and of the internal rotation of the tibia may present the greatest difficulties.

To offer correction of all these components in a single brace is hardly possible, particularly when one is dealing with a deformity of long standing where the resistance of rigid structures against correction is difficult to overcome. Fortunately, in the majority of cases, it suffices to obtain a correction of sev-

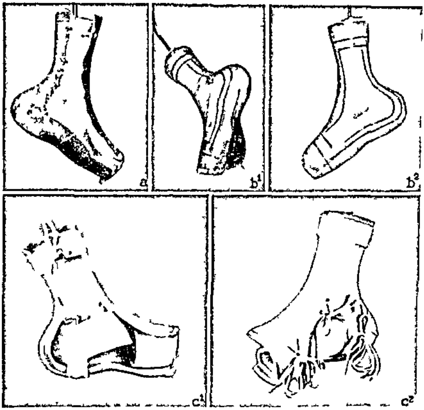


FIG 114 Lange type celluloid club foot night brace (a) The first layer on the corrected model (b¹ and b²) tracing of the piano steel wire (c¹) the finished appliance from the medial side (c²) from the lateral side

eral of these components or to maintain the over corrected position of the foot in the after care of surgical procedures (closed or open) with a less complicated appliance

Before describing a few club foot braces which may serve as examples for effective brace construction for this type of deformity we should like to stress the fact that these braces are primarily intended to maintain a result which has already been obtained by orthopedic treatment

The Celluloid Club Foot Night Brace

Where there are proper facilities for the manufacture of orthopedic appliances according to the celluloid steel technique set forth by F Lange* this procedure has many ad*vantages to recommend its use for a club foot* night brace While there is practically no age limit for use of this appliance it is particularly valuable for our youngest patients Materials for its manufacture will be described in Chapter 5 (Celluloid Plates pages 160-4) and construction principles are identical Any appliance made of celluloid (or fiberglass where it is available and preferred by the prescribing orthopedic surgeon) is light in weight resistant to moisture and able to withstand rough handling It is easily applied even to the small foot of a very young infant and as it allows sufficient space for the growing foot without sacrificing correction it can be used over a long period of time Made to a corrected plaster of Paris model it presents little if any difficulty at the time of fitting Finally because its surfaces are smooth this type of

*Professor Dr Fritz Lange late Professor of Orthopedic Surgery Munich Germany

brace is not likely to lead to the accidental injuries frequently caused by metal appliances

Depending on the patient s age and the degree of deformity the brace may in some instances include the knee joint flexed at right angles in order to control rotation Usually the appliance is limited to the foot and lower leg

For the celluloid club foot night brace a plaster of Paris cast is made with the foot held in the highest degree of correction obtainable The positive model requires additional correction which constitutes the only difficult part in the manufacture of a celluloid club foot night brace Plaster of Paris must be added at the heel in order to permit further correction of the equinus deformity and supination of the heel The forefoot of the model is enlarged laterally that is along the fifth toe to create additional space for increased abduction and pronation of the forefoot The region of the cuboid and the tuberosity of the fifth metatarsal bone remains untouched This constitutes the fixed point on the lateral aspect of the foot in relation to which the corrective forces on the forefoot and the heel will act To avoid pressure on the heel the tuberosity of the fifth metatarsal bone and the external malleolus the model is covered at these points with patches of ½ inch felt The appliance is constructed as an external splint covering the lateral surface of the foot and the lower leg the dorsum and the sole of the foot and the heel and the anterior and posterior surfaces of the lower leg while the medial aspect of the foot and the lower leg is left free This arrangement determines the contour of the appliance If the model is covered with a smooth layer of thin white felt strips of herring bone webbing are cut to the necessary length and pasted on the felt lining with celluloid acetone solution This must be used sparingly in a fairly thick solution to avoid penetration of the felt lining by the celluloid Next the webbing is fixed on the model by many turns of linen thread and one or more layers of the celluloid acetone solution are spread on the webbing and massaged into it until a smooth surface is obtained

The appliance is reinforced with steel wires These are placed on the model according to the mechanical stress to which the appliance must be submitted Such wires must be carefully bent to shape rather than tied on to the model or fixed with tacks so that they do not retain a tendency to move to their original shape and thereby deform the finished appliance or even penetrate the thin layer of celluloid The wires are then imbedded in thick celluloid acetone paste using scraps of webbing and cork meal wherever this is necessary to equalize the surface As soon as this layer is perfectly hard and dry the external layer of webbing is applied If the same webbing is used for the external layer as has been used for the first layer it is advisable to place the strips of the external layer at right angles to the strips of the first layer In many instances it will suffice to use a cover of burlap for the external layer The appliance may then be completed with an additional layer of gauze which offers a better looking finish without requiring too much celluloid Again the webbing or burlap and gauze are firmly attached to the model by frequent turns of the linen threads

When the appliance is completely dry and hard it is cut from the model After the edges are trimmed and beveled it is ready for the first fitting At this time the foot and lower leg are placed into the brace and measurements are taken for the straps and pressure pads which introduce the corrective forces These consist of (1) a strap for the forefoot with a pressure pad over the first metatarsophalangeal joint for abduction and pronation of the forefoot (2) a strap at the proximal end of the appliance which holds the lower leg in place correcting the supination (3) the most important strap a cross strap which consists of a longer strap running from the heel over the instep and a short strap at

right angles to the long strap encircling the heel The center of this cross will lie just below and posterior to the internal malleolus gaining a firm hold on the os calcis This cross strap is intended to correct the supination and adduction of the heel and the equinus deformity The straps carry two laces at each end which go through holes in the celluloid and are tied in position on the outside of the brace At the time of this fitting the proper site for these holes has to be determined in order to obtain the desired correction It is frequently necessary to add a small cuff which encircles the lower leg just above the ankle from which straps or laces are carried through holes on the sole of the brace in the direction of the longitudinal axis of the lower leg This cuff holds the foot firmly in the appliance and adds materially to the effective correction of the equinus

After the fitting the brace is finished by binding the edges and adding the pressure pads and the corrective straps The laces must be long enough to permit the parent or nurse to apply and remove the brace without taking the laces out of the holes in which they have been secured by knots at the ends

This appliance if properly made to a well *corrected model will permit effective correction* of the equinus the supination and adduction deformities It has some influence on a cavus deformity but none on the rotation of the tibia unless the appliance is built to encase the thigh with the knee held at 90° of flexion

In applying the brace the cuff above the ankle is tied before the foot is placed into the brace Next the heel is fixed by means of the cross strap the forefoot is pulled into abduction and pronation by tying the laces of the toe strap and finally the entire foot is pronated by tying the proximal straps of the lower leg The splint may be worn by a small *infant twenty four hours at a stretch but it* must be removed briefly several times a day when the foot should be manipulated After the first year of life when the child starts to stand and walk the appliance has its indication chiefly as a night brace while for a period when the patient is up and about depending on the severity of the deformity a club foot walking brace or a celluloid foot plate should be worn in an adequate shoe

Pre walker Club Foot Shoe

For infants and small children it may not be necessary to resort to the more elaborate construction of a club foot night brace particularly if the original deformity was of mild degree or if a satisfactory degree of correction has been attained by orthopedic treatment In these cases the readily available pre walker club foot shoe serves as an effective day and night brace sometimes in combination with a Denis Browne splint

When the pre walker club foot shoe has become too small it may be replaced by the tarso-pronator shoe which permits continuous maintenance of correction while the child starts to walk

Maintenance of correction during ambulation in the older child requires a Lange type celluloid or fiberglass foot plate to be worn in a regular oxford This frequently suffices to carry the well corrected or milder case toward adolescence In the more severe cases a double bar leg brace or even a Hessing type brace may be indicated

Chapter 5

FOOT BRACES

FOOT BRACES and foot plates generally represent the only concrete knowledge which a layman may have of orthopedics. Advertising campaigns sponsored by shoe factories, drug stores, manufacturers of the various types of foot plates, and even bracemakers have brought these appliances into the limelight. At the same time, and for similar reasons, they have become a Cinderella of the medical profession. Because it is so easy to go to a drug store or surgical supply company to buy a pair of foot plates for any one of the many ailments which afflict the feet of modern man, many physicians consider it beneath their dignity to prescribe such appliances. Even among orthopedic surgeons, opinions about this subject differ widely and many leaders in the field of orthopedic surgery regard the foot brace as a necessary evil which has attracted too much public as well as medical attention. To analyze the reasons why appliances for the feet have been relegated to such an ambiguous position in orthopedics, we shall limit our discussion to the scientific considerations which form the basis of medical opinion.

From the medical point of view, we must deal first with indications and contra-indications for foot plates and, second, with the reason why physicians in general and orthopedic surgeons in particular are so often dissatisfied with the results of foot plates.

Let me state at the outset that foot braces or plates are necessary, that they constitute the most frequenly used orthopedic appliances and, when properly constructed, are among the most rewarding of the orthopedic apparatus. Construction of efficient foot plates is difficult and relatively expensive, requiring a thorough knowledge of the subject on the part of physicians and bracemakers alike. We shall learn further that an understanding of the action of foot braces on the foot and the relation of the foot to the entire body is by no means common knowledge and that misconceptions concerning the function of foot plates are mainly responsible for the disrepute into which these appliances have fallen.

A foot plate is indicated for prophylactic purposes, for correction, or for support.

A foot plate should be prescribed *for prophylactic* reasons as soon as symptoms of fatigue or pain on standing or walking manifest themselves, whenever the gait becomes unstable, or when a patient complains of frequent "turning over" at the ankle or even of sprains of the ankle joint. In most instances, clinical examination will show a certain deviation in the shape of the foot from the normal, a malalignment of the entire extremity, or at least an incorrect relation of the foot to the leg with regard to its static and dynamic function. For patients with no subjective symptoms, the prophylactic use of plates may be indicated if there is a marked increase in body weight (during pregnancy, or in cases of endocrine or alimentary obesity), after fracture of the foot or leg, or following surgery on the lower extremity.

As a means of correction, a foot brace is indicated wherever examination shows deformity of the foot or a faulty static alignment of the extremity, regardless of whether the pathologic condition has already caused clinical symptoms or whether it has been discovered accidentally. In the latter case, correction is necessary only if the condition exceeds

physiological limits This group is by far the largest and includes cases of pes planus, pes valgus, pes transverso-planus and their combinations in various degrees Correction is further indicated for the rare deformities of the foot, such as talipes equinovarus, pes cavus (excavatus), pes calcaneus, and pes adductus anterior, and, finally, for a large group of cases in which a normal foot is found to be in faulty alignment with the other sections of the extremity, as seen, for instance, after a malunited fracture of the ankle joint or of the tibia or in a case of genu valgum or varum All these cases have in common the need for correction of the foot position, while there is little or no need for support For the indications in this group to be fulfilled, flexibility or relaxation of the foot in all its sections is essential *Therefore, a rigid foot must be converted into a flexible or relaxed foot before a correcting foot brace can be built and applied*

The third group of indications for a foot brace comprises cases in which the foot requires *support* but is not suited to correction The end results of corrective procedures for paralyzed feet or for congenital deformities, ankylosed feet following infectious arthritis or osteomyelitis belong to this group, also the rigid pes plano valgus in patients, such as hemophiliacs who cannot tolerate corrective measures or who, for various reasons refuse them In these cases the appliance aims primarily to effect a correct painless distribution of weight and to establish, as far as possible the correct position of the elements of the foot in relation to the line of gravity of the leg

Before discussing in detail recommended types of foot plates and describing the procedure for making them, we have to deal with a number of questions of general interest

Among the main objections raised against the use of a foot plate are that such an appliance would have to be worn forever, and that its continued use would not only cause inconvenience but would also lead to complete inactivity and subsequent atrophy of the muscles of the sole thereby adding further damage to the pathological condition already present.

The first objection cannot be easily repudiated as a time limit for the use of foot plates can hardly be offered except in cases where they are worn merely as a prophylactic measure *To answer the second objection we must* point out that the necessity for foot plates is largely a matter of civilization Throughout his life, civilized man wears shoes with solid soles and walks on smooth solid ground This permanently deprives the muscles of the sole of the foot of adequate stimuli from direct touch and from the roughness and unevenness of natural ground A properly made plate will not interfere with the function of the muscles of the foot and it will not add to the deterioration of the foot caused by modern living Apart from the fact that it is impossible for exercise or surgery to build up a "weak foot" in an adult into an efficient steady, and painless foot for a lifetime, I am convinced that a foot plate does not sufficiently inconvenience the patient to justify other procedures such as surgery or treatment with exercises over a long period of time

Another frequently debated issue is the question of rigid as opposed to flexible foot plates A foot plate for correction or support cannot fulfill the indications for which it is built if it is flexible *It is argued that rigid* plates, made to a plaster of Paris cast of the foot, are only adequate for the foot when standing as they interfere with the propulsion of the foot, and by no means support it in other positions Here let me stress the fact that the action of a correcting or supporting foot brace on the foot is much more important in the standing phase than in motion The reasons are that foot trouble in general, and the most common forms of pes planus and plano valgus in particular, are found among surgeons, factory workers, cooks, bakers, laundresses, and many others whose business or profession necessitates that they stand for long periods of time We rarely find a patient in this group who, like the postman, earns his living while walking with the exception of

those working in large cities where concrete and steel have almost the same influence on the moving as on the stationary foot

These facts are based upon physiological conditions When a person walks the muscles which move the foot and at the same time support its skeleton and its relative position to the lower leg are active When he stands these muscles relax and the weight is borne by the ligaments which in the conditions under discussion sooner or later become over stretched and insufficient We often find that the muscles are still in a position to maintain the proper alignment of the foot and its sections on walking but that a malposition of the foot leading to pain is present on standing long before walking on such a foot becomes painful Frequently an individual who is more or less disabled by a pes plano valgus will be free of discomfort as soon as he leaves the city and goes for long walks in the country It becomes therefore the primary purpose of a foot plate to support or maintain the correct position of a foot on standing and this can only be accomplished by a rigid foot plate made to a plaster model of the foot In studying the different phases of walking the active correcting plate and the passive supporting plate must be considered separately It may suffice here to say that both types of plates will not interfere with the proper propulsion of the foot on the contrary they will save unnecessary and injurious muscle action by changing the faulty alignment of the foot and its sections into a position as nearly normal as possible on standing as well as on walking It is true that rigidity of the materials used for foot braces does not preclude a certain degree of resiliency An elastic or soft foot plate however will do no more and possibly even less for the foot than a well built shoe

There is no doubt that in many cases any type of foot plate will relieve the pain of an aching foot but these "cures" frequently reported by patients and published in the advertisements of the trade are only temporary at best We may account for this so called success in two ways For a large group of patients the deformity of the foot such as a pes planus or plano valgus does not cause pain until incorrect weight distribution has caused the formation of callosities or corns At this stage it is the painful callous that makes the patient cry out for relief and any type of pad—soft hard elastic or rigid—will relieve the pressure from the painful spot and seem to effect a cure For a second group of patients pain originates from strain on the ligaments and joints of the foot or even the entire extremity when the muscles become insufficient as in a valgus deformity of the foot In such cases the muscles are still able to bring the foot into a correct position and to maintain it All that is needed is a reminder or stimulus Any foreign body placed inside the shoe which causes pressure on the sole of the foot when the muscles relax will furnish such a stimulus

H Spitzy introduced a "Kugeleinlage" consisting of a simple insole on which a small marble is fixed corresponding to the longitudinal arch of the foot This is quite effective as an active correcting plate for weak feet in childhood A similar foreign body action" is responsible for the successful results of many of the innumerable foot plates on the market in early cases of foot discomfort

From our discussion of the superiority of the rigid over the flexible foot plate it is understood that a foot plate must be made to the plaster of Paris model of the corrected foot Although the majority of foot plates are

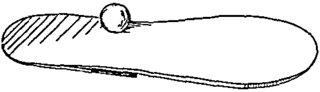


Fig 115 Spitzy s active correcting foot plate for children

sold ready made or built according to the measurements of the foot or to an imprint of the sole of the foot with the patient standing such specifications are never accurate enough for an efficient brace

The plaster of Paris cast the first and most important step in the manufacture of foot braces will prove its superiority over all other techniques provided the mold is properly made First the foot has to be flexible It must yield readily and painlessly to the required correction when the plaster of Paris cast is applied A foot which is rigid and cannot therefore assume the corrected position or one which is still inflamed or otherwise sensitive is not yet ready for a foot plate *It would be an inexcusable mistake* to prepare a plaster of Paris mold of such a foot the one exception here is the deformed foot *which represents the end result of treatment* and cannot undergo further correction In this case we resort to making a passive *supporting plate*

The technique for obtaining a plaster of Paris mold and positive model for a foot *brace has been described in detail in* Chapter 1 and needs no repetition here

Dealing next with foot braces proper we *must remember that almost every* specialist in this field has his own ideas and a preference for certain models or types which best suit *him We cannot* discuss all or even a majority of the widely used appliances for the foot Every orthopedic surgeon and every brace *shop will have quite* a collection of foot plates which have not fulfilled their purpose

Again we shall limit the discussion to the *models which we prefer*

Following the general classification of appliances throughout this book we divide foot *plates into the active correcting* and passive supporting types

The active correcting brace is indicated for *the flexible pes plano valgus* with a predominant valgus component especially in children and younger adults For this purpose we use *a leather covered metal plate shaped* and built according to the instructions of Royal Whitman *This we call the Whitman type foot plate* When properly made it acts forcibly on the position of the foot in its relation to the lower leg mainly correcting the valgus deformity without interfering with an abundant play of the muscles which must be left to correct or compensate for the other deformities of a pes plano valgus which may be present The Whitman type plate acts almost like a vise on the tarsal ring of the foot In its simple original form it does not support or restore a "fallen metatarsal arch nor does it primarily relieve pressure from the metatarsal *heads* Moreover the plate we use does not elevate or even support the so called "longitudinal arch" of the foot to any considerable *extent* We have found that this is not essential if we are dealing with a flexible foot and active muscles In these cases the proper re*lation of the tarsal bones to* each other and of the heel to the weight bearing line of the leg automatically restores correct alignment of *the skeleton While the active correcting brace* of the Whitman type holds the foot in the proper weight bearing alignment on standing and thereby *relieves the respective muscles* and saves their energy it also has a marked correcting effect on the foot in the different *phases of the gait The details of this action* are best described by Royal Whitman *

> The patient instructed to throw his weight upon the outer side of the foot presses down the external arm (of the plate) and thus lifts the internal flange against the inner side of the foot which is instinctively drawn away from the pressure and thus toward the normal contour He no longer turns the feet outward in walking because this causes positive discomfort and he is not likely to resume the passive attitude because of the suggestive lateral pressure of the support *With the foot* held in the normal attitude the patient may again walk with the proper spring thus the brace itself becomes a positive aid in the physiological cure as contrasted with sole plates and stiffened shoes

*Whitman, Royal *A Treatise on Orthopedic Surgery* Philadelphia Lea and Febiger 9th Ed 1930 p 790

Although the active correcting brace is not suited to a foot in which the transverso planus condition constitutes the chief ailment we have found that occasional metatarsal trouble is promptly relieved by the correction which the Whitman type plate affords

The so called "combination Whitman type foot plate" which is widely used has great disadvantages and no scientific justification The active correcting principle of the Whitman type foot plate is lost by adding the metatarsal part and the combination as a whole is unnecessarily bulky and heavy It interferes with muscle action and hampers the elasticity of the gait We therefore recommend only the use of the original simple form of the Whitman type foot plate as the active correcting brace of choice

In an attempt to obtain the superior correction afforded by the original Whitman plate without neglecting metatarsal pain caused by spreading of the metatarsals and faulty weight distribution on the second third and fourth metatarsal heads we designed our own *combination foot brace* This incorporates the greater part or tarsal section of the Whitman plate and uses a small bracket like metatarsal support which acts as a separate unit

The passive supporting type of foot brace we recommend is the *celluloid steel wire plate* as well as the fiberglass and other plastic plates Although the material used for these passive supporting braces has in recent years changed from celluloid to fiberglass and other plastics we shall include a detailed description of the celluloid plate because in the long run it is still superior to the new plastics Furthermore anyone who can make a correct celluloid plate will have no difficulty with the simpler procedures for making passive supporting plates with fiberglass and other plastics

The original celluloid plate was introduced by F Lange in 1903 and has withstood the test of time Patients who have used other types of foot plates either before or after wearing their first pair of celluloid plates have almost without exception preferred the celluloid appliance

One of the conspicuous features of this plate is the lateral border which prevents the foot from slipping off laterally while at the same time enforcing adduction and pronation This border is indispensable for rendering the correction of the valgus position of the heel effective if a medial wedge situated beneath the plate is used for this purpose Were there no lateral flange to the plate the foot would gradually stretch the leather of the uppers of the shoe causing them to bulge over the lateral edge of the shoe sole This is frequently observed with shoes that have been worn for some time by patients suffering from a pes valgus whether or not one of the common types of plates or insoles has been used To be efficient the low external flange of the celluloid plate requires a certain amount of strength since a relatively short lever has to meet a large weight This necessitates a somewhat heavier and bulkier plate than would be desirable There are however many patients requiring a foot plate for whom correction of either the valgus position of the heel or of an abduction of the anterior foot plays only a minor role This may be true in the case of a pes planus or transverso planus but also in milder cases of valgus especially if the higher heel of a woman s shoe corrects part of the valgus position by holding the foot in equinus It was particularly for such women patients that we devised a new modified celluloid plate which has proved very satisfactory This modification the edgeless celluloid plate is indicated where the standard plate with a lateral border cannot be used for a specific reason such as a patient s refusal to wear the larger celluloid plate because of the unattractive appearance of the shoe it requires The smaller modified plate permits correction of at least part of the deformity and thus represents a compromise in cases where the indication for an effective plate correction could not otherwise be met Therefore in addition to the original Lange plate this modified celluloid

plate has its definite indication and justly deserves a place in our armamentarium

The indications for the active correcting and the passive supporting braces and their merits have already been discussed Comparing the two types we find that for each there is a definite indication which is not fulfilled by the other There remains however a group of cases which may use both types on an alternating basis or either type for a definite purpose The Whitman type plate is the stronger device it occupies less space in the shoe and puts more strain on the muscles of the foot and lower leg while obtaining a good correction As it is stronger it will be superior to the celluloid plate for heavy patients or in cases where the patient s work and other circumstances are very unkind to the foot plate If a plate can be worn at all in athletics (provided a proper shoe can be found) the Whitman type plate is generally more adequate than the celluloid plate

Celluloid and some plastic plates (Laminac) give a comforting support to the foot while fiberglass plates are more rigid and are therefore occasionally not tolerated by the very sensitive patient or in the presence of circulatory impairment Though the celluloid plate particularly the type with the outer border occupies more space in the shoe than the Whitman type plate it makes the foot more independent of the shoe and does not require as much additional support from a well fitting shoe as does the active correcting foot brace

THE MODEL FOR FOOT BRACES

The negative plaster of Paris cast or mold and the positive model obtained by casting the mold are the same for both types of foot braces In preparing and shaping the model for work in the brace shop the technique differs slightly For the active correcting brace a well made positive model should not be touched It is placed on the table so that the heel is in neutral position that is within the weight bearing line of the extremity or in a moderate degree of supination or inversion The first metatarsal bone must be plantar flexed and the model stationary on three points the heel and the regions of the first and fifth metatarsal heads

For the celluloid plate the model requires additional handling Where bony prominences have been outlined with the indelible pencil they are covered with small pads of white felt which are fixed to the tuberosity of the fifth metatarsal bone and in individual cases to the sole of the heel (spur of the os calcis) or under the head of the first metatarsal bone (sesamoiditis) Additional pads may be required at the site of a prominent scaphoid or any other bony prominences which may lead to undue pressure and pain The edges of these felt pads are beveled with a sharp knife They are attached to the model with small tacks

THE MANUFACTURE OF METAL PLATES

The Whitman Plate

The shape of the plate is outlined with indelible pencil on each plaster model by the orthopedic surgeon or by an experienced bracemaker Care should be taken that the outer flange which holds the heel in the corrected position is sufficiently high and wide to distribute the correcting force over a sufficiently large surface This flange must be far back toward the heel and should not interfere with or reach to the tuberosity of the fifth metatarsal bone On the medial aspect of the foot the plate should come up to the scaphoid bone As to the length of the plate pressure on the head of the first metatarsal bone and on the sesamoids has to be avoided The plate should therefore reach just proximal to the head of the first metatarsal A pattern is cut from brown paper that corresponds exactly to the drawing on the model and is then outlined on the metal Stainless steel is used gauge 16 18 according to the size of the foot and the weight of the patient Though it requires more labor stainless steel is preferred for all patients as it stands up better under wear and tear is not affected by perspi

ration and does not ruin the interior of a shoe. The weight of the plate does not deserve as much consideration as it usually receives. An active correcting brace of this type will be just as comfortable or even more comfortable if it is heavy than if it is too light. The additional weight will in the majority of cases improve the gait just as a heavy boot worn for skiing or hiking seems to improve it.

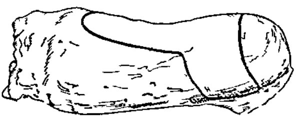


Fig. 116. The contour of a Whitman type plate is traced on the uncorrected positive model. The region of the head of the first metatarsal is not included.

After the plate is cut to the pattern with chisel and hammer, the edges should be polished before the plate is shaped to the model. Frequently overlooked, this is very significant as polishing the edges prevents a breakage in the plate during the process of hammering. No plate should be hammered over an iron last and then fitted to the cast, as this will unnecessarily stretch the metal and it cannot be hammered back again. The metal must rest on the ledge during the hammering and it must never be hammered over a hollow. The plate is hammered slowly to the model, just enough

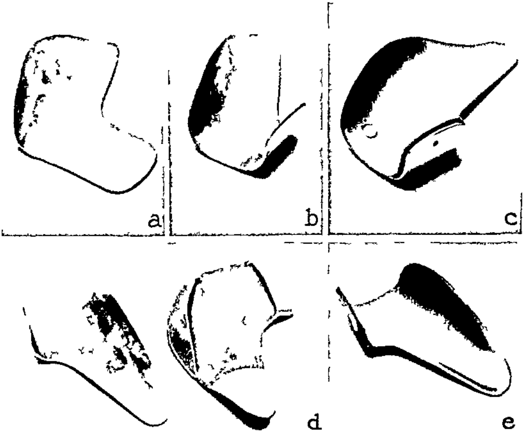


Fig. 117. Manufacture of a Whitman type foot plate. (a) The first stage in hammering the plate to the model. The medial part is almost finished, the edges are polished. (b) The external flange is bent up, the plate is ready for the first fitting. (c) The plate is covered with leather. (d and e) Whitman type foot plate with removable leather cover.

to give it the form of the arch Its heel part must be hammered downward to fit the cast This operation is repeated until the plate is properly formed to the arch and the heel It can now be polished on the inside The outer flange is bent upward over an anvil so that it is not in a position parallel to the longitudinal axis of the foot as the plate should widen toward the fifth metatarsal bone The plate *must fit the plaster of Paris model correctly* especially on the medial and lateral aspects On the sole the longitudinal arch of the plate may in some instances, be flatter than the arch of the cast The plate must balance perfectly on the plane surface of the table and must not fall to either side

Each plate is now ready for the first fitting It is fitted to the foot over the stocking with the patient sitting Next the correct action of both plates is judged with the patient standing on a stool with a plane surface with the longitudinal axes of both feet parallel and the feet moderately apart This allows critical *determination of the fitting of the plate to all* parts of the foot and of the position of the foot and the plate in relation to the weight bearing line of the extremity *If the plate seems cor*rect it is inserted into a suitable shoe after plenty of talcum powder has been used in the shoe and on the plate The patient puts on the shoe with the aid of a shoe horn and the

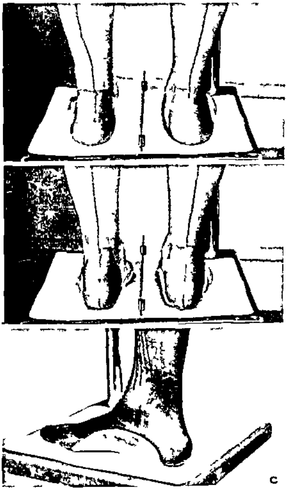


Fig 118 Fitting the Whitman type plate (a) Marked valgus position of both feet (b) Valgus well-corrected (c) The medial aspect of the plate on the foot

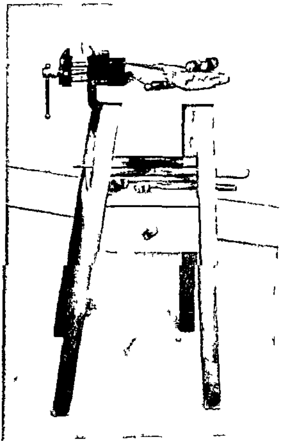


Fig 119 Small workbench for the office with the necessary tools The lead block is held by the vise when plates are hammered

fitting is once more judged with the patient standing in his plates and shoes Finally if everything so far has been satisfactory the patient is sent for a short walk in order to study the action of the foot braces on walking

If the plate has been carefully worked to a correct plaster model of the foot only minor adjustments may be necessary Most of this work can be done where the brace is fitted For this reason a good vise a lead block and a few hammers of various weights should be available If the first fitting has been satisfactory the plate is returned to the workshop where polishing may be completed As a last step the inside of the plate is covered with leather A four ounce russet strap leather is used The leather is cut according to the plate immersed in water for about two minutes and riveted to the plate while wet After the leather is dry its edges are again wetted and it is polished with a cloth It is usually advisable to cover the metal plate with leather In smaller plates a fine calf leather may be used for the lining and a cover may be sewn which fits over the metal plate and may easily be removed for later adjustments of the plate especially for children

New Combination Foot Brace

Our new combination foot brace must be made to a plaster of Paris model of the corrected flexible foot In addition its metatarsal section must be carefully outlined on the skin with indelible pencil to insure correct positioning of the prongs The two component parts fulfill their purpose without interfering with each other The design for the metatarsal section of the plate represents an entirely new concept Instead of attempting to elevate the second third and fourth metatarsal bones by means of a high pad which rarely fits properly unless it is made from plastic material to a plaster model we use a bracket which prevents the splaying of the metatarsals This device which can be made from lighter stainless steel than is necessary for the rear section of the brace has one prong just proximal to the first and fifth metatarsal heads Therefore the metatarsal support on the sole of the foot is less elevated and occupies less space in the shoe than the conventional metatarsal pad

After the two sections have been built to the plaster of Paris model they are connected with a blue steel spring which maintains the distance between the two independent units of the plate at the same time as it adjusts to the curve of the shank of shoes with various heels At the time of the first fitting only one

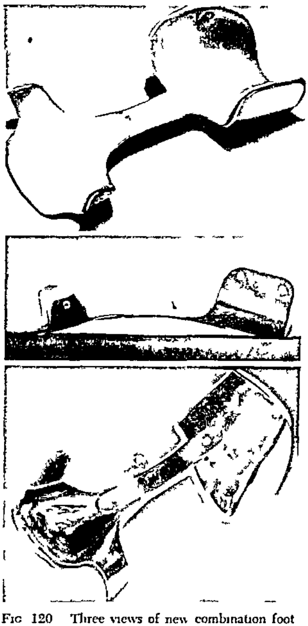


Fig 120 Three views of new combination foot plate

rivet is used to hold the spring to each section of the plate This permits further adjustment of the relationship between the component parts After the first fitting and before the plate is covered with leather a second rivet is driven through both ends of the spring which stabilizes this relationship The metal sections are then polished and the plate is covered with leather

This foot brace represents an almost ideal solution for the simultaneous correction of a flexible pes valgus and transverso planus Correction of the valgus deformity can be increased by placing a small leather wedge under the medial aspect of the heel section of the plate It also has a better patient acceptance than other models Its only disadvantage is the tendency of the steel spring to break at the rivets if this part is not protected against moisture or perspiration

THE MANUFACTURE OF CELLULOID PLATES

The following materials are used in the manufacture of celluloid steel wire plates

1 Celluloid (celluloid scrap) can be obtained at any novelty shop or button manufacturer Unfortunately inflammable celluloid must be employed The use of noninflammable celluloid has been tried with negative results since this material has rendered the final product rather brittle and decreased its durability

2 Acetone as a solvent for the celluloid Any paint store will secure it if it is not in stock

3 Webbing as used in the upholstering of furniture Everything depends on the quality of this webbing if this is poor the final product will also be poor We use herringbone webbing two inches wide and loosely woven which combines the necessary strength with a light weight and with an adequate capacity for absorbing celluloid

4 Piano steel wire of different gauges The normal plates for adults require a 2 mm or gauge #36 wire while for women and children gauges #40 and #44 (1 15 mm) are sufficient Instead of piano steel wire a flat spring steel 1 cm wide and 1 5 mm thick may be used For routine work however we prefer piano steel wire

5 Burlap of medium weight is used for the outer or third layer of the celluloid plate in preference to a second layer of herringbone webbing

6 Pressed cork ⅜ inch thick is available in sheets at cork factories or shoe supply dealers The cork is used for the wedges underneath the heel of the plate It is also ground to cork meal which mixed with the celluloid serves as a filling material for the second layer of the plate

7 A loose cord (hemp) for the imbedding of the wire

8 A strong linen thread for the fixation of the webbing on the model in the process of making the plate

9 Fine calf leather for lining and suede leather for the sole

The technique for making a celluloid plate is difficult to describe and quite complicated as much attention has to be given to minor details A person experienced in celluloid work however will gather sufficient information from the following description to be able to turn out correct celluloid plates

The plaster of Paris model which represents the foot in its corrected position must be perfectly dry and smooth before it is ready for application of the first layer The only permissible correction of the model is the preparation for a metatarsal support in the case of a pes transverso planus The distal margin for this support has been determined on the foot and consequently on the negative and positive models by the indelible pencil marks The metatarsal pad must be of sufficient height to relieve weight bearing from the heads of the second third and fourth metatarsal bones At the same time it must permit weight bearing on the heads of the first and fifth metatarsal bones The latter requirement limits the width of its transverse diameter The metatarsal pad of the finished celluloid plate has a definite contour unlike the metatarsal pads of the

many types of plates on the market. The distal edge (toward the toes) is its highest part and drops vertically down to the sole. The edge is straight or slightly convex toward the heel of the foot. Moreover, the metatarsal pad becomes narrower and flatter toward the longitudinal arch of the foot. To obtain such a metatarsal support on the finished plate a corresponding depression must be cut out of the sole of the model. This is done with a strong knife or, even better, with a chisel that cuts the distal edge where the cavity has the greatest depth and gradually prepares a proper excavation.

To prevent undue pressure of the plate over bony prominences such as the tuberosity of the fifth metatarsal bone and exostoses of the first and fifth metatarsal heads or a spur of the os calcis, the model needs further preparation. The places which have been outlined with the indelible pencil are covered with pads of thin white felt fixed to the model by means of tacks, and the margins are beveled with a sharp knife. Finally, two large tacks or nails are driven into the plaster on the dorsum of the model to which is attached the strong linen thread used to hold the webbing in place.

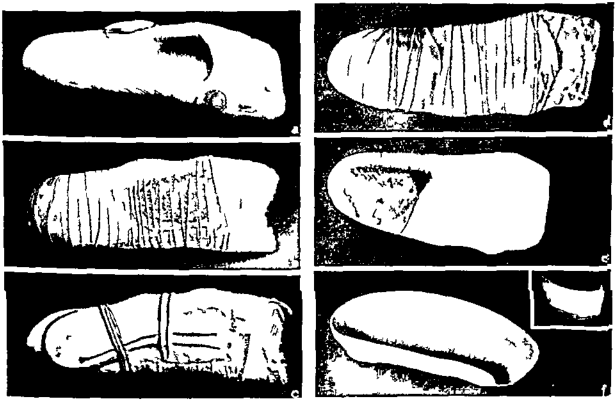


FIG. 121. (a) Plaster of Paris model for a celluloid plate. The metatarsal excavation is prepared and a felt pad covers the tuberosity of the fifth metatarsal bone. (b) The model is covered with the first longitudinal layer of webbing; a cork pad presses the webbing into the excavation for the metatarsal support. Note the bulging at the tuberosity. (c) The piano-steel wire for a Lange type plate is placed over the first layer. For this purpose double wire is used. The "horseshoe" wire is already imbedded. The proximal transverse wire is shown between two pieces of hemp cord. The filling of the metatarsal pad with cork meal celluloid is still visible. (d) External layer of the herringbone webbing. (e) A medial wedge of cork is fastened to the heel of the plate, which is trimmed for the first fitting. (f) The Lange celluloid plate has a strong lateral border. Insert shows the medial wedge at the heel.

The necessary quantity of celluloid scrap (three parts to ten of Acetone) is dissolved in Acetone in an airtight container and stirred until it becomes smooth and cream like in consistency

The celluloid plate consists of three main layers the internal layer made of longitudinal straps of webbing the steel wire skeleton embedded in celluloid with the aid of loose hemp cord and with cork meal celluloid as a filling material and the external layer of burlap or transverse straps of webbing

For the first layer a piece of 2 inch herring bone webbing is cut from the roll corresponding in length to the U shaped contour of the plate from the base of the big toe following the internal border of the foot around the heel to the fifth toe This first strap is applied to the model from the big toe around the heel to the little toe encircling the foot like a horseshoe It forms the outer and inner margins of the plate the heel cap and nearly *two-thirds of the sole It is usually not difficult* to place this strap as the webbing may be slightly stretched and pressed until it covers the model and is free from creases The strap is held in place by many turns of the strong linen thread attached and reattached to the nails on the dorsum of the model. When the first strap is in place a small area of triangular shape (gusset) remains An additional piece of herringbone webbing is cut exactly to the pattern of the uncovered area of the model and inserted into this space by pushing it under the circular turns of the thin thread. *At this point* the entire model is covered with the first layer of webbing and care must be taken to hold the material on the model completely flat avoiding creases and lumps as well as even the smallest uncovered spaces The webbing is then covered with the celluloid cream by means of a hard brush or preferably a knife with a wide blade and the celluloid is forcibly massaged into the webbing This is one of the most important features in the process of making durable and light celluloid plates The finished plate must represent a homogeneous mass of celluloid and webbing or burlap with the steel wires imbedded rather than separate onion like layers of webbing burlap and celluloid For this purpose a sufficient amount of labor has to be devoted to the proper massaging of the *celluloid cream into the* webbing It is best *done as already stated* with the blade of a strong knife and this movement may be repeated several times until the coat is perfect

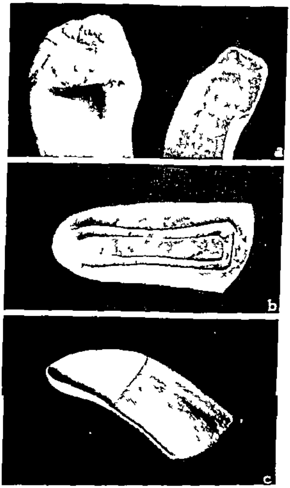


Fig 122 (a) Metatarsal pad corresponds exactly to the excavation on the positive model Note the sharp and steep anterior border of the excavation (b) U shaped double wire on celluloid *plate is partly imbedded (c) Small celluloid* plate dispenses with the large lateral border leaving a narrow rim at the heel The heel part of the plate is covered the anterior part still shows the structure of the first layer

In a plate with a metatarsal support it is sometimes difficult to force the webbing into the excavation provided in the plaster model A few cuts into the webbing as well as thicker celluloid cream may be helpful To hold the first layer down to the bottom of the cavity a small piece of cork or wood of corresponding size is tied on to the model until the first layer is completely hard It is then removed and the hollow is filled in with a tough mixture of cork meal and celluloid Drying of the first layer on the model takes approximately twenty four hours It is possible of course to hasten the process of making a celluloid plate This should not be encouraged however as complete hardening of each layer will add to the durability of the finished product and at the same time save weight and bulk

The second layer is composed of the steel wire structure The original placing of the wire requires one longitudinal and two transverse wires as illustrated in Figure 121 Our modification of the "skeleton" of this celluloid plate substitutes two new U shaped wires for the original longitudinal wires with the basis of the U running transversally across the metatarsal region and its open end facing the heel The two U shaped wires are the same for our modified celluloid plate without the lateral border as for the original Lange plate In the latter the two transverse wires are laid across the U shaped wires Wherever the 2 mm or gauge #36 piano steel wire does not suffice to bear up under the body weight it is simply doubled The proper placing of the wire is another prerequisite for the light weight and durability of the celluloid plate The second layer of the plate requires therefore the aid of a skilled mechanic while the celluloid work is usually left to the leather worker The piano steel wire is kept ready in the customary length the ends are flattened on the anvil Bending of the wire is accomplished with two pairs of pliers and a small vise This procedure is difficult only where two wires cross each other especially where the transverse wires cross the longitudinal wire or the U shaped wires These crossings have to be made very accurately, otherwise the plate will become too bulky As soon as the wires are properly placed they are encircled with loose hemp cord in order to achieve a uniform level and a better imbedding The ends of the cord slightly exceed those of the wires Wires and cord are then fastened to the model by means of a thicker celluloid paste and the entire second layer is again secured by means of many circular turns of the strong linen thread The entire surface of the second layer is now leveled by means of celluloid Where a greater unevenness has to be filled in cork meal is used to advantage as the cork meal celluloid mixture undergoes less shrinkage when dry than the celluloid cream alone The thickness of the second layer is determined by the thickness of the steel wire and should under no circumstances exceed the level of the wire at any place When the second layer is finished the shiny surface of the steel wires must be visible within the celluloid Again the plate has to be kept in a dry place for at least twenty four hours

The third layer is usually made of burlap of medium weight Originally herringbone webbing was used placing the straps transversally that is at right angles to the straps of the first layer Webbing for the external layer makes the plate stronger but at the same time heavier than is necessary in most cases Moreover it requires greater skill and more labor than the simple procedure of cutting a one piece cover from the burlap The burlap is easily stretched over the model It is fastened with circular turns of the strong linen thread It may also be fastened to the model with a few tacks in the region of the heel to secure better fitting Celluloid cream is now repeatedly massaged into the burlap until a perfectly smooth surface is obtained When the celluloid is completely hardened which again requires twenty four hours any remaining unevenness is smoothed out with sandpaper As a last cover a rather thin celluloid cream may be spread over the surface with a paint brush

Finally a square or triangular piece of pressed cork is placed on the heel of the plate while it is still on the model Rather thick celluloid cream is used for this purpose and a strong cord is needed to hold the cork in place The size shape and position of the cork depend upon the requirements of the individual case In the majority of cases a medial heel wedge is needed to correct the valgus position of the heel

As soon as the entire plate including the cork wedge is completely dry it is cut from the model with a sharp knife Prior to the fitting it should be given some time to dry on the inside as frequently the plaster of Paris has retained a little moisture Before the plate leaves the workshop its edges are trimmed with a sharp knife or with strong scissors and if necessary the internal surface is smoothed out with sandpaper The plate is again placed on the model and remains there until the time of the first fitting

FITTING THE CELLULOID PLATE

The plate is taken from the model and fitted to the patient's foot over a stocking If the plaster of Paris cast has been correct and the plate properly made it will fit exactly to the foot holding it in the position of the desired correction The margins of the plate are now trimmed with a sharp knife to the proper form and size Next the cork at the heel is shaped with a knife and a rasp to give the desired correction of the valgus position To test whether the amount of correction is sufficient the patient is placed on a high stool with a horizontal surface or better still a special examining stool or table with the long axes of both feet running parallel The plates are placed under both feet and the height and the shape of the wedge are changed until the os calcis is securely held at the correct place within the weight bearing line of the extremity

The patient has been instructed to wear a suitable pair of shoes for the fitting usually an oxford shoe of the Blucher type which has not yet yielded to the deformity of the foot The plates are then inserted into the shoes and covered with talcum powder the patient puts on his shoes with the aid of a shoe horn If the plate fits well in the shoe and shoe and plate fit well to the foot the patient is again placed on the examining stool so that it is possible to judge whether the desired position of the plate in the shoe has been obtained If this is the case he is sent for a short walk in order to test the effect of the plate on walking

The celluloid plate being a very sensitive appliance requires more adjustment than the active correcting Whitman type brace Before it is finished it has to be tested over a sufficient period of time so that the amount of correction may be precisely regulated The patient is told to wear the unfinished celluloid plates in the same pair of shoes to which they were fitted for several hours daily preferably in the early morning over a period of from two to five days He must then return for a final adjustment of the plates if necessary Thereafter the plates are sent to the workshop placed on the model and may require another coat of celluloid before they are lined with thin calf leather or shirting Finally the plates are marked *right* and *left* on the outside and delivered to the patient

THE MANUFACTURE OF FIBERGLASS FOOT PLATES

By ALFONS R GLAUBITZ

In this procedure the plaster of Paris model is "screened down" using window screen wire to obtain quickly a smooth plaster surface Three coats of parting lacquer may be applied without waiting for the model to become completely dry More recently Polyvinyl alcohol film has been used in preference to the lacquer The Polyvinyl alcohol sheet is placed in a damp towel for three minutes and then pulled over the model and bound tightly A layer of Dacron felt is applied in the same manner over the Polyvinyl alcohol sheet Three to six layers of glass cloth are stretched over the model and covered with Dacron felt for a smooth surface on the outside

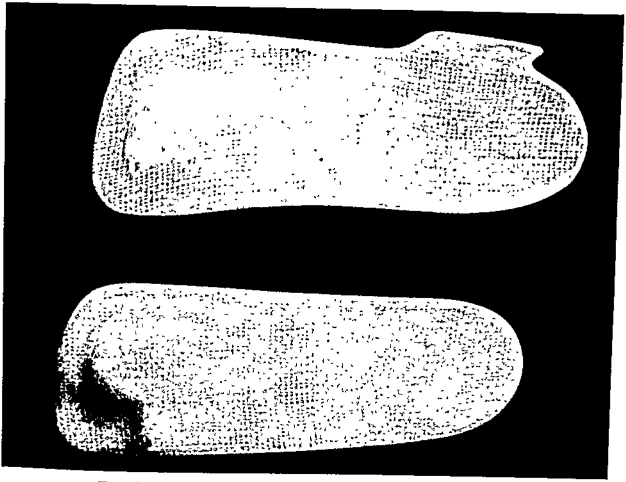


Fig. 123. Fiberglass metatarsal plate with and without lateral flange.

Orthobond A and B are mixed and rubbed in with tongue depressors or spatulum Finally, a second Polyvinyl alcohol sheet is applied and the appliance is bench cured for one hour The plate is cut off the model and is then ready for fitting

The same technique may be used with slight modifications for other orthopedic appliances where fiberglass is preferred to celluloid or Laminac

THE MANUFACTURE OF LAMINAC FOOT PLATES

By Paul Schumacher

Laminac, a resin used for construction of plastic arch supports of varying densities, comes in two strengths #4110, which is rigid or glass hard, and #4136, which is flaccid or completely soft With a mixture that is composed of 75 per cent of the rigid component and 25 per cent of the flexible type, the final result is a plastic that is strong yet contains some flexibility and is similar, in this way, to celluloid By increasing the rigid component, a tougher mixture is produced and of course, the reverse is true

The plaster of Paris technique follows the procedure for making celluloid plates except for the fact that three coats of lacquer must be applied when the model of the foot is ready The second and third coats may be applied only when the preceding layer is thoroughly dry Next, a Polyvinyl alcohol bag is made to the contour of the support After nylon stockinette is applied to the cast in four layers, the Polyvinyl alcohol bag is used to cover the cast, leaving a hole or pouch through which the resin is poured in sufficient quantity to impregnate the various layers of nylon After a curing period of about two hours the plate may be removed and trimmed

In closing this chapter, we would like to feature two small, very useful appliances the *leather metatarsal corset* and the *great toe spring steel splint* Both are worn inside the stocking

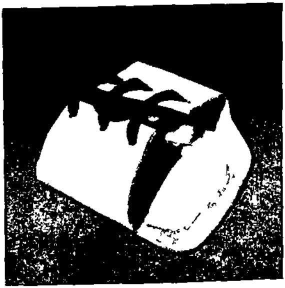


Fig 124 Leather metatarsal corset

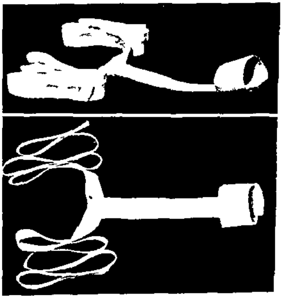


Fig 125 Great toe spring steel splint for hallux rigidus flexus

Chapter 6

APPLIANCES FOR THE UPPER EXTREMITIES

We have deferred our discussion of brace construction for the upper extremities mainly because the conditions of this part of the body requiring orthopedic appliances are considerably fewer than those for the spine or the lower extremities. Furthermore, lesions of the shoulder girdle and the arm demand orthopedic treatment less frequently than those of the spine and legs. As surgery is usually more effective for treatment of the upper extremities, a brace is seldom indicated and rarely worn for more than a limited period. Moreover, a defect or lesion affecting one arm is not likely to disable a patient to the same extent as a deformity of a leg. As we know, both legs form a systemic unit, while each arm must be considered as an independent unit. Thus a patient with one normal upper extremity will be more or less inclined to neglect the disabled or useless side and quite frequently will not use the prescribed appliance properly. Finally, the principles of brace construction for the upper extremities differ very little from those described for the appliances for the spine or the lower extremities. In addition, the materials and workshop techniques are the same. For these reasons we shall refer to previous chapters for such details. Weight bearing and consequently unweighting of the extremity play no role in brace construction for this part of the body.

We shall, however, encounter new problems in the design of a useful brace for the arm. The upright carriage of the human being has freed the upper extremities from the tasks of weight bearing and locomotion. The individual arm as a whole has acquired a range of motion and a variety of functions no longer comparable to the fairly simple and limited tasks of the leg. In addition to the vital mechanisms of supporting, pulling and pushing the body, of gripping and holding, of feeding and cleaning, protecting and fighting, the human arm and hand serve as a means of expression for many primarily psychic functions (Braus). To meet these unlimited demands, the arm has gained a much greater range of motion. This is achieved not only by an increased motility of its sections afforded by the build of its joints, but also by the freely movable suspension of the arm at the shoulder girdle. The latter may be compared with a movable platform which carries the lever system of a crane. It is obvious that the most ingenious brace construction cannot imitate or substitute for even a part of the vitality of a normal arm. The complex anatomy which gives the upper extremity its great range of movement and its versatility does not offer a secure attachment and fixation for an orthopedic appliance. For anatomical reasons the thorax cannot afford the same stability for an arm brace as does the pelvis for the lower extremity.

Several appliances for the upper extremity require a plaster of Paris mold of the shoulder and the arm or one of its sections. This is true whenever molding leather or plastics are to be used. Specific examples include a Hessing type brace for a pseudarthrosis or a flail elbow and an appliance to prevent recurrent dislocation of the shoulder. When preparing the plaster mold, we maintain the limb in the desired position. At times this may be difficult, as in the case of pseudarthrosis of the humerus, for the reason that the small dimen

sions of an arm may cause the surgeon's hand to interfere with the application of the plaster of Paris. In such an instance traction applied at the elbow by means of adhesive tape or strips of webbing glued to the skin with Mastisol* will be helpful. *Similarly traction* may be applied to the fingers, or finger grips made of galvanized steel wire may be used.

*Mast sol (n d Mast gau) Glo ga and Co Ch cago 26 Ill no s

Orthopedic appliances for the upper extremities may be classified into two groups.

1. Appliances which are used temporarily as part of the general orthopedic treatment. This would include for example braces *to immobilize a joint in a desired position* to prevent development of a contracture or to correct an already existing deformity. The *apparatus includes the abduction splint for* the shoulder, appliances used in the treatment

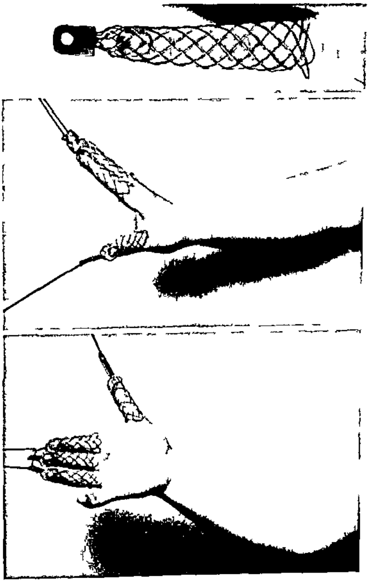


FIG 126 Finger traps of galvanized wire hold forearm and hand in the desired position when preparing a mold

of obstetric paralysis or birth palsy, braces for the correction of a flexion or extension contracture of the elbow, wrist or fingers, and, finally, splints which are used in the treatment or after care of fractures, such as the "baseball finger," and appliances which serve to immobilize or support sections of the upper extremity during the long period of recovery following nerve injury

2 Braces which are intended for a permanent function comparable to an artificial arm Examples would include a molded leather steel arm brace for a flail elbow joint or for a pseudarthrosis of the humerus or of the forearm which for some reason cannot be successfully treated by surgical procedures appliances for a recurrent dislocation of the shoulder joint, a brace which immobilizes the wrist in a position of dorsiflexion or the thumb in opposition, in order to restore usefulness of the part for certain gripping functions in case of partial paralysis

It is obvious that all such appliances are concerned with *motion* They either eliminate abnormal and excessive motion or they make motion possible by means of fixation

The requirements of the individual case vary so greatly that standardization, which we prefer for the routine of the brace shop, is less practicable than it is for spinal and leg braces The technique for building an appliance for the upper extremities does not differ basically, as stated above, from the manufacture of braces for other parts of the body

To illustrate the principles underlying brace construction for the upper extremities, we shall describe a limited number of appliances

THE ABDUCTION SPLINT

Of all the appliances for the upper extremities we consider the abduction splint the most valuable Its use should be much more universal than we have found it to be Whenever immobilization of the shoulder joint or fixation of the arm becomes temporarily necessary, the shoulder joint should be placed in abduction of 90° The arm must rest comfortably supported down to the fingers on a splint holding the humerus 25° to 40° in front of (anterior to) the frontal plane of the body The elbow may be held at a right angle, the forearm in pronation or neutral rotation, and the wrist in dorsiflexion the position of function" The abduction splint may serve as a means of fixation in the treatment of a fracture of the humerus, preventing motion at the shoulder and elbow joints Devices for traction can be incorporated into the appliance On the other hand, the abduction splint may be used to support the arm in a favorable position as in the case of a fracture of the bones of the forearm which are immobilized in a plaster of Paris cast extending from the fingers to the humerus In an adult, the treatment of fractures of the arm, regardless of their location (with the exception of some simple fractures at the wrist and of fractures of the metacarpal bones and fingers) must consider two common evils development of a contracture at the shoulder joint and impairment of circulation Both occur when the arm is carried in a sling or and this is worse, fixed to the body by means of adhesive tape or bandages Here the use of a well fitting abduction splint is indispensable Circulation of the arm continues under optimal conditions and the development of an adduction contracture at the shoulder joint is prevented In addition to its value in the treatment of fractures the use of the abduction splint is even more important in the so called "minor injuries" to the shoulder region which, if neglected, frequently cause a disability far beyond what might be expected from the original trauma Whether we term the resulting condition of the shoulder joint bursitis frozen shoulder," or periarthritis humero scapularis the arm should be rested on the abduction splint Its use immmediately following even a minor injury to the shoulder speeds recovery and prevents the development of a contracture of the shoulder joint which is both painful and difficult to treat

Furthermore, to improve circulation and prevent the development of a contracture at the shoulder the fixation of the arm at 90° of

abduction and 25° to 40° in front of the frontal plane relaxes the deltoid muscle and the pectoralis major The deltoid muscle may suffer from disuse and over stretching to such a degree that complete paralysis may be simulated Although there is no injury to the circumflexed nerve, the prevention of such damage to the deltoid muscle is one of the great assets of the abduction splint

The main objection to the use of this appliance outside of the indications for which it is generally recognized, comes from a patient who for several reasons refuses to wear this appliance while he is ambulatory The brace is said to be uncomfortable and awkward with clothing While wearing the brace, the patient *finds it difficult to get around, especially in* traffic Moreover, the physician may doubt its effectiveness in the area of fixation and immobilization and prefer to use a plaster of Paris spica We feel, however, that with proper construction these objections are not valid and should never interfere with the universal use of the abduction splint where indicated

To fulfill its purpose, the splint must afford good fixation of the shoulder joint proper in the desired position It must also be a true ambulatory or portative appliance, light in weight, and small enough to permit the patient to wear ordinary clothes with only minor alterations As a rule, this appliance is made to individual measurements within a few hours To meet the requirements for which it is designed, the brace must introduce the three *forces of a three-point system as shown in the* insert in Figure 127 Theoretically, two of the

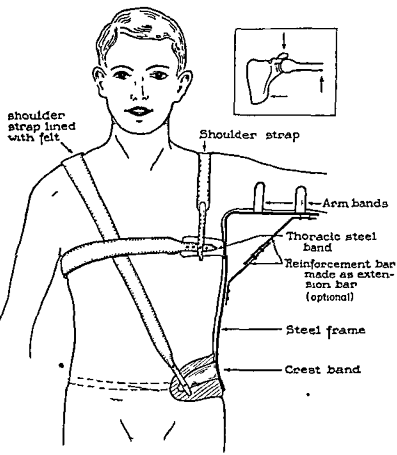


Fig 127 Working drawing of abduction splint The insert (redrawn from Hans von Baeyer) shows the three point system which must be active

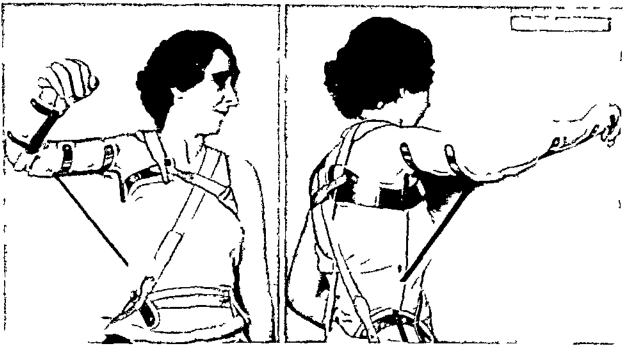


Fig. 128. Abduction splint for the right arm

three forces will act on the scapula and one on the humerus. Instead of introducing two forces at the scapula with one acting vertically downward on the acromion and the other horizontally from without on the lateral margin of the scapula, the brace must secure the position of the shoulder girdle with relation to the arm on the thorax. It is essential that the brace remains well within the axilla and displacement in any direction on the thorax must be avoided. Two metal bands secure the position on the thorax. The proximal one, just below the axilla, encircles one-quarter or one-third of the thorax and serves as attachment for strap and buckle, completing the circle. The distal, smaller, metal band should be well padded and rest on the iliac crest. To this iliac band, the most important strap and buckle are attached which serve to carry the weight of the appliance and the arm on the opposite shoulder. In many instances, these two straps are sufficient to hold the abduction brace in place. A third, circular strap, at the level of the iliac crest, may be added. A shoulder strap on the side of the brace is optional. Additional straps and buckles or straps with Velcro are used to maintain the position of the upper arm and forearm on the arm section, and a small strap is used to hold the hand on the cock-up splint.

As this appliance is frequently used for a very short period of time (five to seven days following manipulation of a "frozen shoulder") it is customary for us to re-use the metal parts of the splint and replace only the felt pads and straps.

For the manufacture of an individual abduction splint, we use ½ inch by ⅛ inch round edge high carbon tool steel for the longitudinal bar which supports the arm, forms the right angle at the axilla, and ends on the pelvic band at the iliac crest (crest band). The thoracic and crest bands are made of 2¼ inches by $\frac{1}{16}$ inch sheet metal or of Alcoa aluminum 2024 T4. The semi-circular or smaller transverse bands are made of 1½ inches by $\frac{1}{16}$ inch sheet metal and are riveted to the longitudinal bar which supports the entire arm. The crest band may be hammered to shape from 16 gauge sheet steel which widens at the middle where it is riveted to the upright longitudinal bar. For a heavy patient, the

main right angle of the abduction brace may be reinforced by a diagonal reinforcement bar of ½ inch by ⅛ inch round edge high carbon tool steel made as an extension bar should the position of the arm at the shoulder need to be changed A simple joint occasionally with a set screw for fixation may be introduced at the elbow to permit flexion and extension while the hand rests on a small transverse bar The distal end of the brace is built exactly like the small cock up splint for the wrist to be described on pages 182 4 The brace is padded and lined with large pads of ½ inch white felt at the axilla and the crest band Finally the brace is fitted with straps and buckles or straps and Velcro for the thorax and the arm respectively

If this abduction splint is properly made it will not only fulfill the medical indications but will also be comfortable for the patient As always exact fitting to the contour of the body without undue pressure on sensitive parts will make even a larger and heavier appliance more comfortable than a small light brace which tends to move away from the body and *is unable to guarantee proper immobilization* or support

Where the arm must remain on the abduction splint without interruption day and night *the patient will be more comfortable in bed if* the abduction splint is suspended at its horizontal section (at the wrist or elbow) by means of a sling from the ceiling or the over *head frame of a fracture bed*

THE STRAPLESS ABDUCTION SPLINT

During World War II a new strapless abduction splint was developed which introduces the three point system required for all orthopedic appliances While this appliance is not sufficient for immobilization and fixation of fractures of the arm it eliminates some disadvantages of the major abduction splints

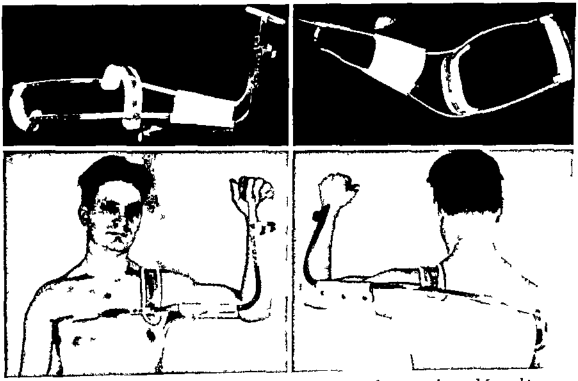


FIG 129 Strapless abduction splint for the arm This appliance can be used for right or left side and it adjusts to all sizes

This splint uses the weight of the normal upper extremity to balance the injured arm against the forces of gravity and contractures It eliminates the straps required to maintain the correct position of the large abduction splint, discussed above, and avoids pressure on the lateral chest wall and on the iliac crest of the affected side It incorporates adequate extensions to permit adjustment and fitting to the adult patient of average size by means of screwdriver and bending irons It is therefore not necessary to build the splint to individual measurements Simple to manufacture and suitable for mass production, this splint can be used for the right and the left arm It is very light in weight and easily dismantled for storage and shipment, requiring only a minimum of space

BRACES FOR RECURRENT DISLOCATION OF THE SHOULDER JOINT

Most cases of recurrent dislocation of the shoulder joint can be successfully treated by surgery It is the rare case that requires a restricting orthopedic appliance, and then only for a short period of time Where surgical procedures are refused or contra indicated, a number of appliances may be recommended These must, of course, restrict motion at the shoulder to a considerable degree if they are to prevent a dislocation of the humerus Such appliances, built along more simple lines, are frequently used with hemophilia patients to prevent distension of the capsule and possible dislocation of the shoulder by recurrent hemorrhages Among the many acceptable constructions that have been published, the Hohmann brace has been highly effective in our experience The author describes the manufacture of his brace for recurrent dislocation of the shoulder as follows

Two oval pressure pads, measuring approximately 3½ inches x 6½ inches are cut from very thin sheet metal or duraluminum (Alcoa aluminum 2024 T4) and shaped to the contour of an accurate plaster of Paris model of the shoulder Both pressure pads are connected with a light metal bar which runs over the acromion This vise is held in place by means of a strap around the thorax, 1¼ inches to 1½ inches wide The thoracic strap, which is closed in front by a buckle, attaches to the anterior and posterior pressure pads by means of a V-shaped strap The attachment of the two V shaped straps at the pressure pads and their connection with the thoracic strap permit some motion at these points in order to avoid a displacement of the pressure pad vise at the shoulder joint by movements of the body and the arm The arm proper is held in a leather cuff which runs from the axilla distally, measuring 3 inches to 3¼ inches in length The upper arm cuff attaches to the shoulder section of the brace by means of three straps and buckles, the lateral of these three straps being riveted to the metal bar over the acromion, while the anterior and posterior straps are riveted to the corresponding pressure pads *

Hohmann claims as main assets of this brace, which he has used successfully in a large number of cases, an extraordinary range of motion for the arm, safety for the shoulder joint, and the fact that it is light in weight (approximately one half pound) We have used a similar brace construction for suspension of the arm, permitting only very limited motion to prevent distension of the shoulder joint during hemorrhages in hemophiliacs

In the treatment of *obstetrical paralysis or birth palsy* an orthopedic appliance has its definite place It is not relevant to discuss the etiology and the various forms of a so called birth palsy Whether the condition is due to injury to the cervical plexus, to fracture of the humerus, or to dislocation epiphysiolysis or simple sprain of the shoulder joint, the symptoms are alike and require treatment at the earliest possible moment The arm is held in a marked degree of internal rotation and active abduction and elevation above the shoulder

*Prof Dr Georg Hohmann *Orthopädische Technik* Ferdinand Enke Verlag Stuttgart, 1958

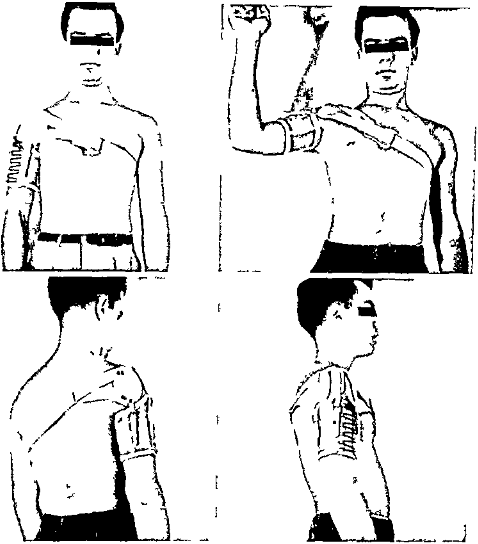


Fig 130 Hohmann type brace for recurrent dislocation of shoulder

level are impossible It is therefore necessary to support and immobilize the affected arm from the very beginning in a position of 90° of abduction and complete external rotation at the shoulder joint right angle flexion of the elbow and neutral rotation or supination of the forearm To maintain the desired position in a new born infant it is not advisable to use an abduction splint with the forearm section in the vertical position as may be permissible for treatment of similar conditions in an older child For the new born and the small infant a plaster of Paris shell or bed should be made which includes the trunk the head and the arms in the position described It is advisable to use several layers of gauze or crinoline (the size of which is predetermined by the measurements of the baby) soaked in plaster of Paris cream in preference to plaster of Paris bandages In place of the plaster of Paris bed we have occasionally used a very simple light and inexpensive appliance made of strong cardboard cut to a pattern The side walls are sewed together at the corresponding corners to hold them in position and the appliance is covered and

lined with moleskin Holes are punched out for loops of tape which hold the small patient in the desired position

Although of different origin and frequently different in symptomatology we must mention spastic paralysis of the arm in infantile spastic hemiplegia Usually in this condition the arm is more affected than the leg and there is also a certain degree of paralysis in addition to the predominant spastic element The picture may somewhat resemble that of an obstetrical paralysis The affected arm is

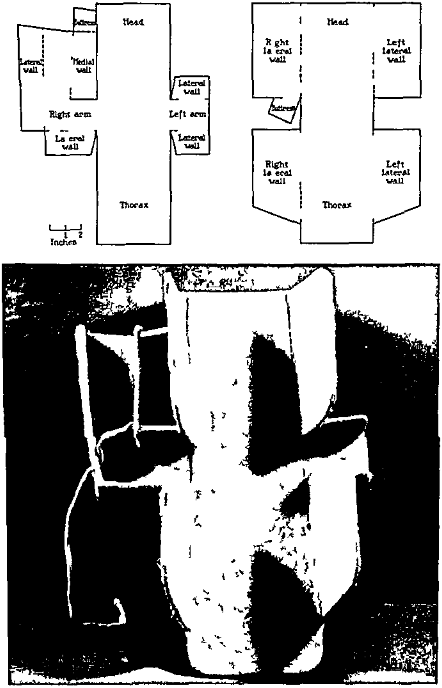


FIG 131 Cardboard bed for the treatment of obstetric paralysis (right arm) The cardboard is cut in two sections according to the pattern shown above

held in internal rotation and adduction, the elbow flexed, the forearm pronated, the wrist flexed, the thumb drawn into the palm and enclosed by the fingers which are flexed at the metacarpophalangeal joints and may be hyperextended or flexed at the interphalangeal joints Depending on the severity of the case, some or all of these symptoms may present themselves in varying degrees Here, the main object of treatment by orthopedic appliances is to prevent contractures which are bound to occur with the paralysis and the constant hypertonus of the muscles Cleverly designed, well made and properly applied orthopedic appliances can be most effective in this area

The plaster of Paris shell with the arm-piece or the abduction splint with the forearm section in vertical position may be necessary for the treatment of spastic hemiplegia early in life Sometimes the tendency towards adduction and internal rotation of the arm is of a moderate or mild degree but, at the same time, there are present a marked pronation of the forearm and a similar spasticity of the hand and fingers For such a child we designed a *simple combination brace* which consists of three main parts

1 A dorsal splint for the hand and the forearm, cut from light sheet metal, preferably Alcoa aluminum 2024 T4, to a tracing of the contour of the forearm and hand with the forearm in supination, the wrist in moderate dorsiflexion, the fingers extended, and the thumb abducted The splint is lightly padded, and the palm of the hand and the fingers are held in position by loops of narrow tape through slots in the metal, while the wrist is fixed with a strap and buckle, and the forearm with a cuff and lacing A special hook-shaped fixation device is riveted to the radial edge of the hand section of the splint in order to hold the thumb in abduction and extension This part of the appliance is built to correct the typical malposition of the spastic hand

2 A small leather cuff for the distal half of the upper arm, riveted to a dorsal Alcoa aluminum 2024-T4 shield

3 An abduction splint for fixation of the shoulder joint at a right angle, attached to the body by means of a thoracic and pelvic band and a system of straps This part of the brace ends distally with a cuff for the upper arm similar to that described in point 2

The forearm hand section of the brace may be rigidly connected with either the upper arm cuff or the abduction splint by means of a small, rectangular bar which fits into a simple device on the dorsal surface of the forearm and on either of the two upper arm sections The details of this construction, particularly of the fixation device for the rectangular bar at the elbow, are readily understood from Figure 132

The rectangular bar at the elbow connecting the forearm section of the brace with the upper arm, with the elbow flexed to 90°, controls rotation of the forearm which is held in complete supination This is an essential feature of the brace as the pronation contracture of the spastic arm is most difficult to

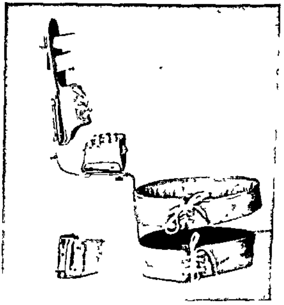


FIG 132 Combination brace for day and night treatment of the arm in spastic hemiplegia The *appliance is assembled for use with the abduction* brace The small cuff for the upper arm, which may be worn instead of the abduction brace, is shown separately.

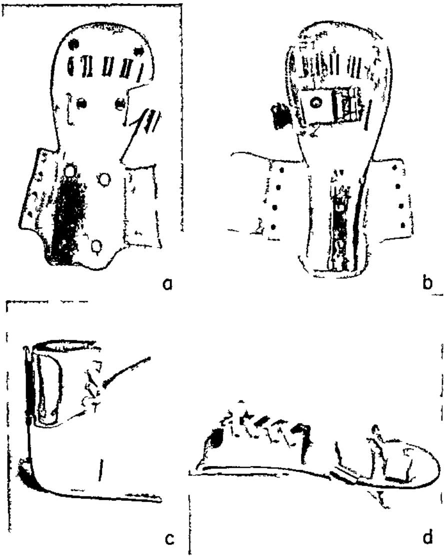


FIG 132 (cont'd) (a) Forearm splint inside view Note the hook for the thumb (b) Outside view Note the double flange attachment for the angle bar (c) Upper arm cuff attached to the angle bar (d) The forearm brace with straps for hand and fingers

correct The idea of this combination brace is to maintain the corrective forces on forearm wrist hand and fingers continuously day and night while at the same time limiting correction of the milder degree of internal rotation and adduction at the shoulder to the night and according to the requirements of the case to some time during the day Thus the small patient may be freed from the larger appliance without sacrificing the continuous correction of the condition of the forearm and hand in the hope that his general development may be encouraged if he is up and about with only a small brace that does not interfere too much with his activities

THE HESSING-TYPE BRACE FOR THE ARM

A molded leather steel skeleton brace of the Hessing type for the upper extremity is indicated for treatment of pseudarthrosis of the humerus or of one or both bones of the forearm in cases of destruction of the elbow joint or the wrist without complete ankylosis in hemophilic arthropathies and for treatment of a high degree of paralysis of the muscles

resulting in a flail joint especially at the elbow A brace will have to be worn constantly if surgical procedures have failed have been refused or are contra indicated To offer the extrinsic support of an orthopedic appliance in place of the intrinsic stability of the arm a molded leather steel skeleton brace is the appliance of choice and is vastly superior to any other brace construction An accurate plaster of Paris model of the arm must be made in the desired position using when necessary the aids mentioned at the beginning of this chapter (see page 168) The brace made to this plaster of Paris model must be designed according to the individual case in order to restore the usefulness of the arm as far as possible At the same time it must be no larger or heavier than is necessary to accomplish its purpose

First of all the type and location of the lesion to be treated must be considered The fixation of a severely damaged elbow or a flail elbow in a paralytic case requires an appliance which includes the arm from the shoulder to the wrist or if pronation and supination must be controlled even to the metacarpophalangeal joints of the fingers In a pseudarthrosis the outline of the brace will depend not only on the site of the pseudarthrosis but also on the amount of motion which is present A complete pseudarthrosis of the humerus with no stability whatsoever particularly if situated in the middle or proximal third of the humerus will require a brace which includes the shoulder and reaches distally to the wrist In a pseudarthrosis of the humerus close to the elbow joint it may suffice to include the upper arm without including

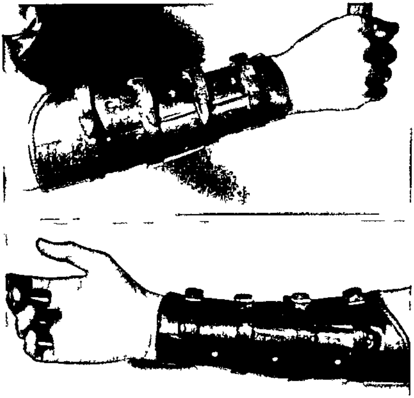


Fig 133 Molding leather Hessing type brace for the forearm Used here for delayed union of fracture of both bones of the forearm

the shoulder while a pseudarthrosis of the forearm may be effectively stabilized by means of a leather casing from elbow to wrist molded over two light longitudinal steel bars

Where fixation of the elbow joint is required it is important to consider the patient's profession or occupation As a rule a flexion of 90° constitutes the optimal position for the universal use of the arm A farmer or a carpenter for example or a clerk who writes a great deal will be better off with a fixation of the elbow at an obtuse angle As always in the field of orthopedic appliances it is necessary to analyze the condition and the requirements of the individual case before designing a brace

The technique for building a Hessing type brace for the arm is carried out in accordance with the detailed description for leg braces in Chapter 4 Some modifications however are necessary An orthopedic appliance for fixation of the arm requires much less strength than one for the lower extremities The reinforcement unit consisting of set screw plates and steel bars may be omitted For a brace with an elbow joint two light longitudinal steel bars joined at the elbow and connected by two semi circular bands of light sheet metal or Alcoa aluminum 2024 T4 for the upper arm and two for the forearm will be used A molded leather brace without an elbow joint may frequently be built with two longitudinal steel bars only with the strength of the molding leather alone guaranteeing sufficient stability In addition the molding leather section may be generously perforated with holes to reduce the weight of the brace and allow free perspiration Instead of eyelets or hooks and lacing a number of circular straps and buckles or Velcro may be used For fixation of the elbow joint in one or several positions for example at an angle of 160° 90° and 60° a locking mechanism may be used on the lateral longitudinal bar

For protection or immobilization of the elbow fiberglass has largely replaced molding leather for jointless braces or one piece splints as well as for the more complicated orthopedic appliances with free elbow joints or locks at various angles and for braces introducing corrective forces to overcome a flexion or extension contracture Inasmuch as in hemophilic arthropathies elbow joints rank second in frequency of involvement (knee joints rank

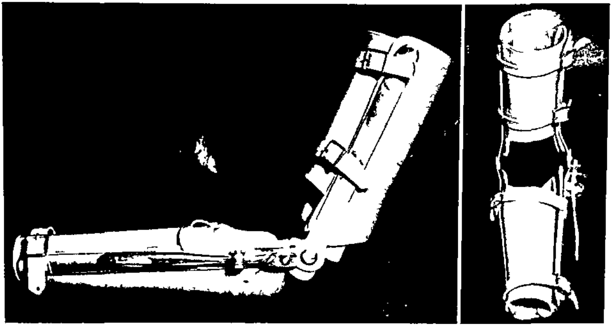


FIG 134 Fiberglass elbow brace with adjustable lock joint on the lateral bar

Fig. 135 Fiberglass brace for upper extremity combining protective support with attachments for corrective forces for elbow and wrist The dorsal sections for upper arm forearm and hand are made of fiberglass the anterior sections of foam rubber padded leather with straps Note universal joint on dorsum of wrist which permits immobilization of wrist in any desired relation of forearm and hand *The longitudinal bar for elastic bands to correct flexion contracture at the elbow can be removed*

first) we have used fiberglass arm braces extensively on hemophilia patients The rigidity of fiberglass eliminates the need for steel or aluminum bars so that metal bands and parts are used only for joints and for introduction of corrective forces In addition a jointless fiberglass splint for the arm is used by hemophiliacs as a brace for swimming For this purpose plastic straps are used

Many *conditions of forearm* hand and fingers especially post traumatic contractures can be successfully treated by "active splinting For this purpose a most useful collection of splints has been designed by the late Sterling Bunnell past master of hand surgery As these are commercially available and can readily be seen in the illustrated catalogues of manufacturers and suppliers of physical therapy equipment a description of the series may be omitted

Where an extension contracture of the four *long fingers must be treated* the so-called Kruckenberg glove" is widely used This consists of a leather or fabric glove with strips of tape or elastic sewn on to the dorsal aspect of the fingers from the base of the proximal phalanx to the finger tip These four strips are tied to a wrist band which also holds the glove in place As a rule this glove is worn at night It is a simple device helpful in correcting post traumatic extension contractures of moderate degree

As many contractures of the fingers are associated with a contracture of the wrist the majority of appliances in this group may not be limited to the hand and fingers alone The correction must also include the wrist thus *necessitating a brace which includes the fore* arm almost up to the elbow As it is very difficult to construct a fairly simple appliance that will introduce corrective forces simultaneously at the wrist and at the phalanges we prefer to correct a deformity of the wrist first We then immobilize the wrist in the desired position and proceed with treatment of the contractures of the fingers as a second stage In general the forearm the wrist and the palm of the hand to a level just proximal to the metacarpophalangeal joints will be included in a molded leather brace made to the *plaster of Paris cast of the limb with the wrist* held in moderate dorsiflexion obtained by the earlier treatment Devices for correction of the deformity of the fingers are easily attached to such a molded leather steel skeleton brace

To illustrate the construction of such a brace we should like to describe a *brace for the treatment of Volkmann's contracture*

A Volkmann's ischemic contracture which

usually follows a supracondylar fracture of the humerus in children, but is also seen in hemophiliacs from hemorrhages into the musculature of the forearm, is one of the most disabling conditions affecting the arm Once it exists, it is almost impossible to restore even part of the function of the hand In a typical case, the elbow is flexed, the forearm is pronated, and the wrist presents a flexion deformity, while the fingers are hyperextended at the metacarpophalangeal joints and flexed at the interphalangeal joints If the case is one of long standing the arm is atrophic, and shorter than the sound arm because of disturbance in growth The skin is glossy and atrophic Sensory disturbances with ulceration of the fingers may also be present In the absence of marked sensory impairment, this condition forms a suitable indication for treatment by Mommsen's Quengel method, which has obtained remarkable results As a rule, the initial Quengel treatment is followed by the use of an orthopedic appliance Such a brace may consist of a molded leather casing with steel reinforcements, including the forearm, the wrist and the hand from the elbow to the proximal interphalangeal joints of the fingers, holding the metacarpophalangeal joints in moderate flexion The brace has its opening on the ulnar aspect of the forearm and the hand, and is closed by means of hooks and lacing A separate attachment holding the thumb in abduction and extension consists of a thimble like loop for the terminal phalanx of the thumb and a spring riveted to the molded leather-steel brace on the radial side at the wrist A small pressure pad is riveted to the spring at the level of the metacarpophalangeal joint of the thumb While immobilizing the wrist in dorsiflexion and the metacarpophalangeal joints in moderate flexion, the terminal and second phalanges of the fingers are not included in order to permit active and passive movement of the interphalangeal joints and to enable the patient to use his fingers for certain activities To prevent recurrence of the flexion deformity at the interphalangeal joints an attachment for the brace has been designed

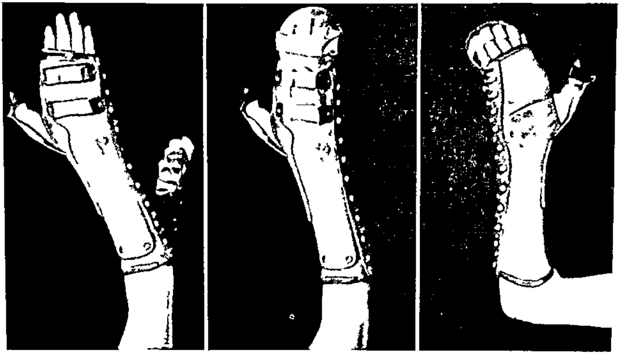


FIG 136 Molded leather forearm brace with spring attachment for the thumb and removable shield for the fingers in the treatment of Volkmann's Ischemia

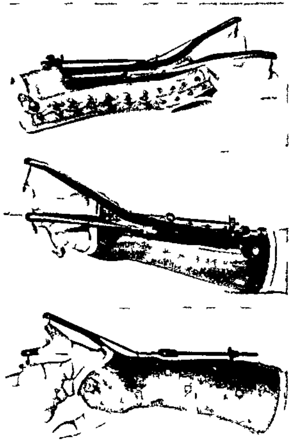


FIG 137 Molded leather brace for correction of flexion deformities of the fingers In the case shown the flexion contracture of the third and fifth fingers was caused by injury to flexor tendons

which holds the fingers in full extension during the night and if desirable during part of the day This attachment consists of an Alcoa aluminum 2024 T4 shield cut to the contour of the four fingers with proximal extensions This shield is inserted with its proximal extensions into two transverse metal bands which are riveted to the brace over the dorsum of the hand It is slotted for a strip of tape which holds the terminal phalanges of the fingers in loops

By placing the fingers into these loops and inserting the shield into the two transverse bands on the dorsum of the brace the fingers are securely tied in full extension

THE COCK UP SPLINT

One of the most useful orthopedic appliances for the upper extremities is the small light cock up splint which permits immobilization of the wrist in the desired degree of dorsiflexion The splint does not require a plaster of Paris model but is made of a longitudinal bar cut from sheet metal or Alcoa aluminum 2024 T4 to a pattern To support the palm of the hand the longitudinal bar carries at the distal end a T shaped cross piece of sufficient length to permit bending up at a right angle at the second and fifth metacarpal bones For attachment to the forearm two transverse bands are required one at the wrist and one at the proximal end of the appliance corresponding to the distal border of the proximal third of the forearm While the two transverse sections for the forearm form a right angle with the longitudinal bar the cross piece for the hand is cut to form an angle of 75 80° with the longitudinal bar The entire appliance may be cut in one piece It is hammered to shape on the lead corresponding to the form and shape of forearm wrist and hand Prior to this it must be determined whether the splint is to be used for a right or a left arm as the cross bar for the hand must form an angle of 75-80° with the longitudinal bar on the ulnar side and the larger angle on the radial side The longitudinal section is hammered slightly concave with the middle part of the cross bar supporting the palm convex toward the palm while the two transverse bands for the wrist and the forearm are hammered to a semi circular shape The brace requires no padding and it is covered with leather The leather for the three cross bars is cut to sufficient length to form a strap which immobilizes the forearm and the hand on the volar splint, using a stud on the external or ulnar end of each cross piece and a number of holes in the free end of the strap if Velcro is not available A volar brace for dorsiflexion of the wrist made according to the procedure described forms a very neat appliance which may be worn almost inconspicuously while

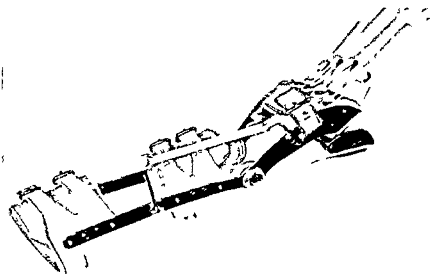


FIG 138 Gutter splint for Volkmann's Ischemia (Courtesy Alfons R Ghubitz)

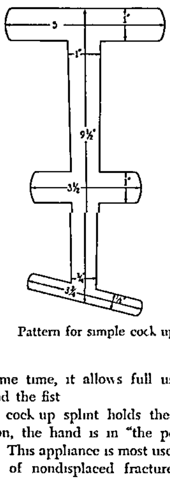


FIG 139 Pattern for simple cock up splint

at the same time, it allows full use of the fingers and the fist

As the cock up splint holds the wrist in dorsiflexion, the hand is in "the position of function" This appliance is most useful in the treatment of nondisplaced fractures at the wrist, particularly in older patients, and in the after care of fractures that have been treated by closed reduction and casts or by surgery It is indispensable in the treatment of the so called "tennis elbow," epicondylitis lateralis humeri, where it maintains the wrist in maximum dorsiflexion for a period of six weeks or more to eliminate extensor carpi radialis pull at the lateral epicondyle of the elbow

THE PLASTIC FOREARM BRACES

Another useful appliance for this region is *the fiberglass or Laminac brace*, which accomplishes complete and uninterrupted immobilization of the wrist, usually for a fracture of the carpal navicular, over a period of many months This appliance is made to a plaster of Paris model with the hand in dorsiflexion and ulnar abduction, corresponding in outline to the plaster of Paris cast in common use for this fracture If the fiberglass brace is fitted with plastic straps, the patient may take a bath

HOHMANN BRACE FOR DISTAL RADIO-ULNAR ARTICULATION

Recurrent subluxation of the distal radio-ulnar articulation, with the ulna dorsally prominent, may be very painful and disabling

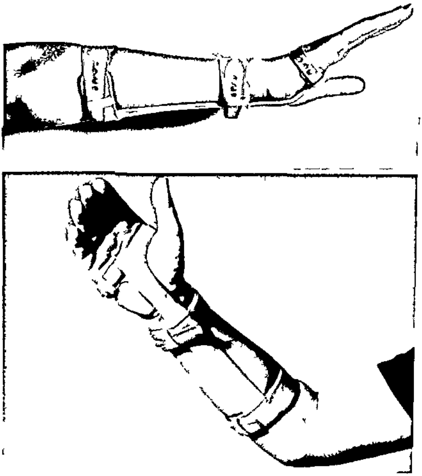


Fig 140 Cock up splint for the wrist cut to the pattern shown in Figure 139 Note complete freedom for flexion of the metacarpophalangeal joints

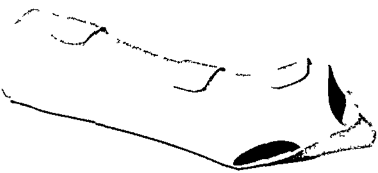


Fig 141 Laminac forearm brace with Velcro straps

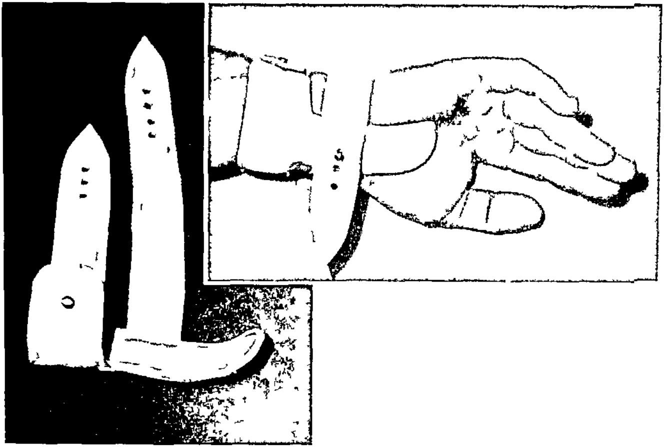


FIG. 142 Hohmann brace for recurrent subluxation of distal radio ulnar articulation

The condition is not rare although its diagnosis is often overlooked Conservative treatment with a small orthopedic appliance designed by Hohmann has been very effective provided that the appliance is properly fitted Although it is quite difficult to make and fit this brace correctly the technique must be mastered or the appliance becomes useless

SPLINTS FOR EMERGENCY OR TEMPORARY USE

Emergency splints and splints for temporary use to immobilize or protect the elbow forearm wrist or hand can be made from the type of aluminum slats used in the manufacture of Venetian blinds These slats are cut to desired lengths and have a remarkable degree of resiliency The strength and rigidity of such a splint can be increased by placing two three or more slats on top of each other and connecting them with a rivet at each end This is similar to a carriage spring consisting of several leaves The aluminum slats are covered with a sheet of thin white felt and applied to the arm with an elastic bandage of appropriate width

The recently designed emergency splint for immobilization of the elbow at any desired angle has found universal acceptance especially among hemophilia patients This splint consists of two sheet metal sections joined with a ratchet screw and lined with ½ inch wide felt The construction of this appliance is readily seen from Figure 143 The splint is applied with one or two ACE bandages and does not interfere with refrigeration of the arm by means of cold packs This adjustable emergency splint is also used for immobilization of the knee joint

A small splint for immobilization of the terminal phalanx of a finger in hyperextension is used for fractures at the base of the ter

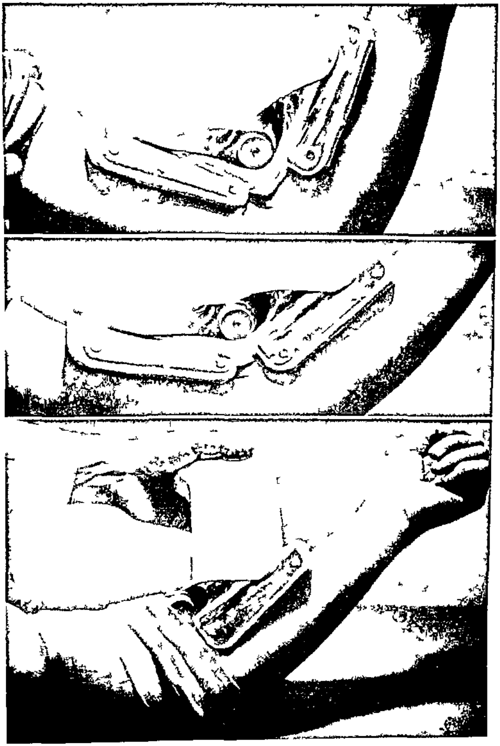


FIG 143 New hemophil a emergency splint for tl e elbow

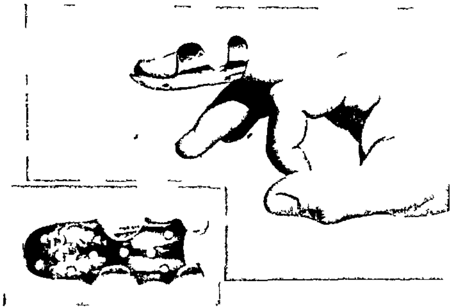


Fig 144 Self holding stainless steel "baseball finger" splint

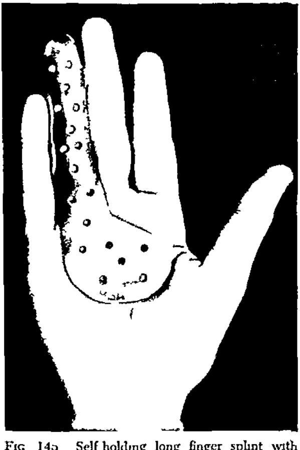


Fig 145 Self holding long finger splint with hand plate

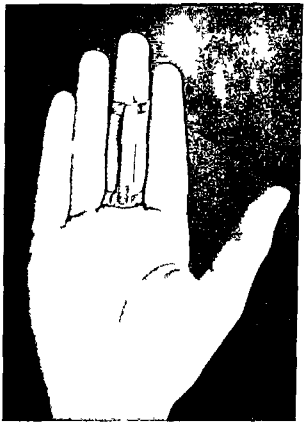


Fig 146 "Trigger finger splint

minal phalanx at the insertion of the extensor tendon the *so-called baseball finger"* The appliance consists of one piece of thin stainless steel or Alcoa aluminum 2024 T4 cut to a pattern of the finger The splint is hammered on the lead to conform to the volar surface of the finger with the terminal phalanx held in hyperextension It fixes and protects the terminal phalanx right to the end A number of holes may be drilled into the metal to *maintain the skin in good condition* The splint is held in place by two flanges on either side which gain a firm grip on the middle or the proximal phalanx When this volar splint fits snugly to the finger the flanges are adjusted by bending the steel to permit the introduction of the finger Once in place the flanges are further tightened around the finger with the aid of pliers or a vise so that there is sufficient pressure to hold the splint securely without interfering with circulation Stainless steel while more difficult to shape is preferable as it is not subject to corrosion The splint may be worn constantly for the required time It allows *full use of the hand except for the section of* the finger under treatment The hand may be washed without removing the splint and even a glove may be worn

This splint may be made in any desired length and used for immobilization of the entire finger If a metacarpophalangeal articulation requires immobilization the splint is extended into the palm where it ends in a small plate that is held in place by a circular elastic around the hand

Another very simple finger splint is used in the treatment of the so-called "trigger finger" If used early in the development of this condition it may effect a cure and eliminate the need for surgery The splint consists of two spring rings one fitting the proximal and the other the middle phalanx These are connected with a small longitudinal steel bar *The splint can be worn day and night* as it prevents the degree of flexion which leads to the painful trigger finger phenomenon without interfering with the general functions of the finger

Chapter 7

THE USE OF X RAYS IN THE FITTING OF ORTHOPEDIC APPLIANCES

FOR MORE than thirty years we have stressed the importance of roentgen examination for scientifically correct fitting of orthopedic appliances for the spine and the weight bearing lower extremities

In the first edition of this book we devoted considerable space to detailed discussion of x ray technique for long distance exposures of the spine that enabled us to study cases of kyphosis and scoliosis and to evaluate the corrective action of spinal braces designed and fitted for these deformities Since then however x ray equipment has been perfected to the extent that a long distance exposure of the spine with a film focus distance of 78 inches (2 meters) has become a matter of routine and no longer requires special apparatus to produce excellent undistorted films of almost the entire spine

Long distance exposures of this type with the patient standing erect and wearing a spinal brace should be taken at the time of the second fitting of a passive supporting or active correcting spinal brace and again when the finished appliance is delivered Similar check up x rays should be taken at

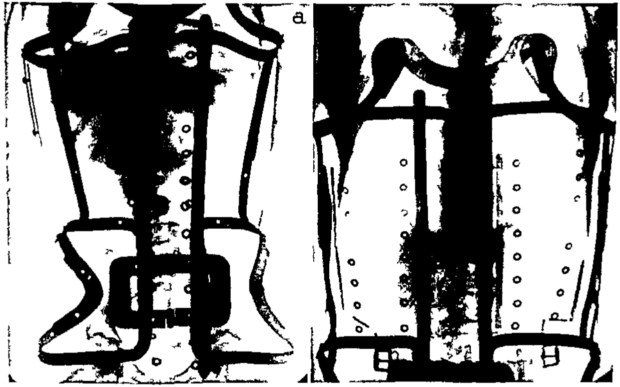


FIG 147 X ray control of passive supporting spinal brace (a) Paralytic scoliosis (b) Spondylitis ankylopoetica

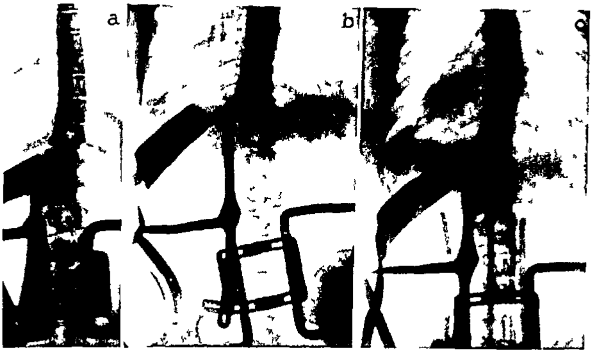


FIG 148 X ray control of active correcting spinal brace (a) Correct action of pressure pad (b) As pelvic frame rotates brace is ineffective (c) Same patient good correction

FIG 149 Congenital dislocation of hip With patient wearing the Hohmann type brace shown in Figure 95 x ray taken at second fitting shows the position of the pelvic band the trochanteric joint and the pressure pad to be too high The brace must be changed accordingly

regular intervals to determine the continued effectiveness of the brace and the necessity for alterations Only one single film is needed for such a check up perhaps twice a year Fear of too much exposure to radiation may thus be alleviated

The recognition of roentgen examination as a useful method in the construction and proper fitting of orthopedic appliances was "still far from general" when the first edition of this book was written in 1938 I am afraid it is still far from general although correct fitting and action of many orthopedic appliances should be checked by x ray This is especially important for braces for excessive shortening of a leg or for a Hohmann brace designed to maintain reduction of congenital dislocation of the hip as well as for *passive supporting braces as shown in the* illustrations

Roentgen examination of the correct fitting of orthopedic appliances is of paramount importance and has become a standardized function *never to be omitted in the treatment of*

hemophilia patients

Every hemophilia Hessing brace for the lower extremities must be checked with x-rays to determine the relationship of the knee and ankle joints of the brace to the anatomical or natural axes, as the slightest incongruence between these axes produces shearing forces on motion This leads to hemorrhages into the joint, which will not occur if the brace fits correctly

These x rays are taken with the patient wearing his brace, standing and bearing full weight on the extremity As a rule, only a single, true A P exposure is made on a small 5" x 7" or 8" x 10' film placed directly on the back of the knee or ankle Both the film and the x-ray beam should be well centered at the level of the axis to be examined to avoid distortion X ray equipment must be adaptable to the height of the patient to direct the centerbeam as indicated X ray examination is not indicated where the brace is constructed without ankle or knee joint as there is no risk that shearing forces will lead to bleeding if there is no joint motion

X ray examination of the position of the foot in a hemophilia Hessing brace for fixed equinus or equinovarus deformity should be made with A-P and lateral exposures with the patient standing and bearing weight to ascertain that the entire foot is well supported by the sandal of the brace and that the longitudinal axis of the tibia is perpendicular to the ground whenever possible Attention must be paid to maximum support at the heel to avoid excessive weight on the ball of the foot and crowding of the toes

While we have emphasized the absolute need for the use of x rays in the orthopedic treatment of hemophilia patients, we must reiterate that it should also be common practice to insure correct fitting and lasting effectiveness of spinal braces and appliances for the lower extremities by means of periodic roentgen examinations of all patients

FIG 150 X ray shows correct position of the foot in the brace for excessive shortening of the leg, illustrated in Fig 112

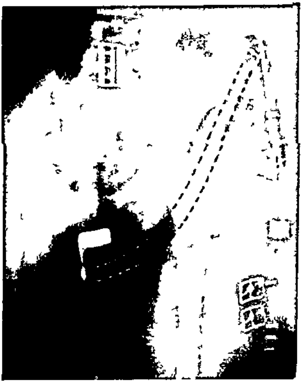


FIG 151 Slipped femoral capital epiphysis X ray control of ischial strap seat

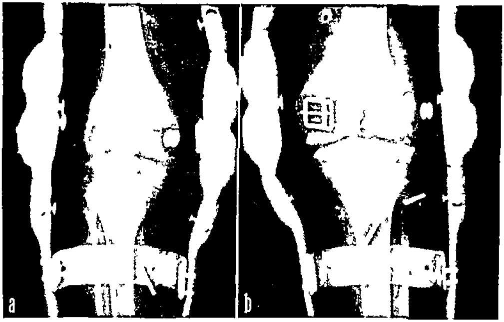
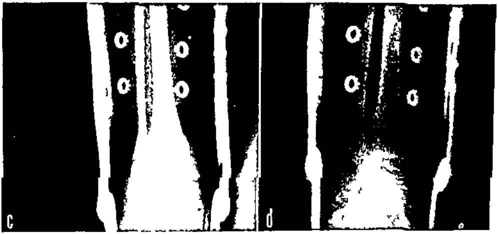


FIG 152 (a and b) X ray control of correct fitting of hemophilia Hessing brace for patient with hemophilic arthropathies right and left knee (c) X ray check up of brace fitting at right ankle shows brace joint too low causing recurrent hemorrhages into ankle joint (d) Correct placement of brace ankle joint in line with anatomical axis



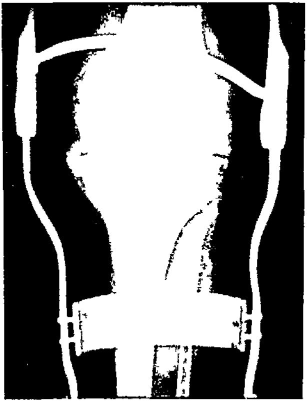


Fig 153 X ray check of patient age thirty wearing hemophilia Hessing brace with Swiss knee lock

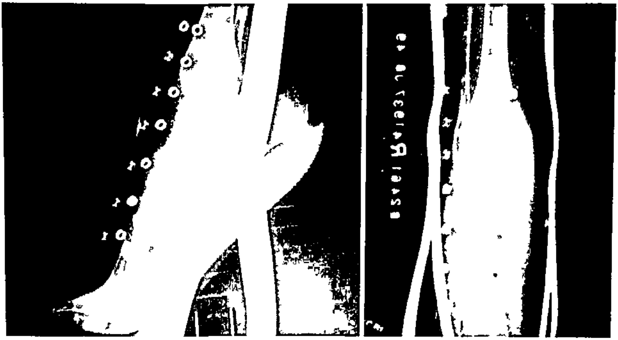


Fig 154 X ray check of patient age eighteen in weight bearing position Equinus deformity of extreme degree secondary to hemophilic myopathy has obtained maximum benefit from conservative treatment Free ambulation with hemophilia Hessing brace incorporating cork platform to support entire foot in equinus

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